

Concrete Box-Units for Housing

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Dear Dean Porter:

In partial fulfillment of the
requirements for the degree of
Master of Architecture,
Advanced Studies,
I hereby submit this thesis
entitled,

CONCRETE BOX-UNITS FOR HOUSING

Respectfully,

Kay Louise Kuhne Ting

Concrete Box-Units for Housing

This paper is dedicated to my family,
my husband Samuel Chao Chung and two
daughters, Jeanne and Amy, for the
tremendous support, patience, and
understanding they have given me.

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Abstract

This thesis has two main parts: the first is a general introduction to industrialization and an attempt to discover trends in housing; the second is a documentation of the design process and results for CONCRETE BOX-UNITS FOR HOUSING.

Part I presents current views of evolving industrialization in the housing industry and some recent statistics. Advantages and disadvantages are given, as well as considerations of investment requirements, need for aggregated markets, and the competition of alternate methods and products. Existing aspects of the housing industry such as financing, labor relations, organizational types, codes, and regulations are discussed. Also included are changing patterns of management, services, and public policy.

Part II details the design development for a stacking concrete box-unit system for housing that is prefinished in the factory. Limits of the material, manufacturing process, transport, and erection are presented. One chapter gives load capacity ratings for various crane types with charts.

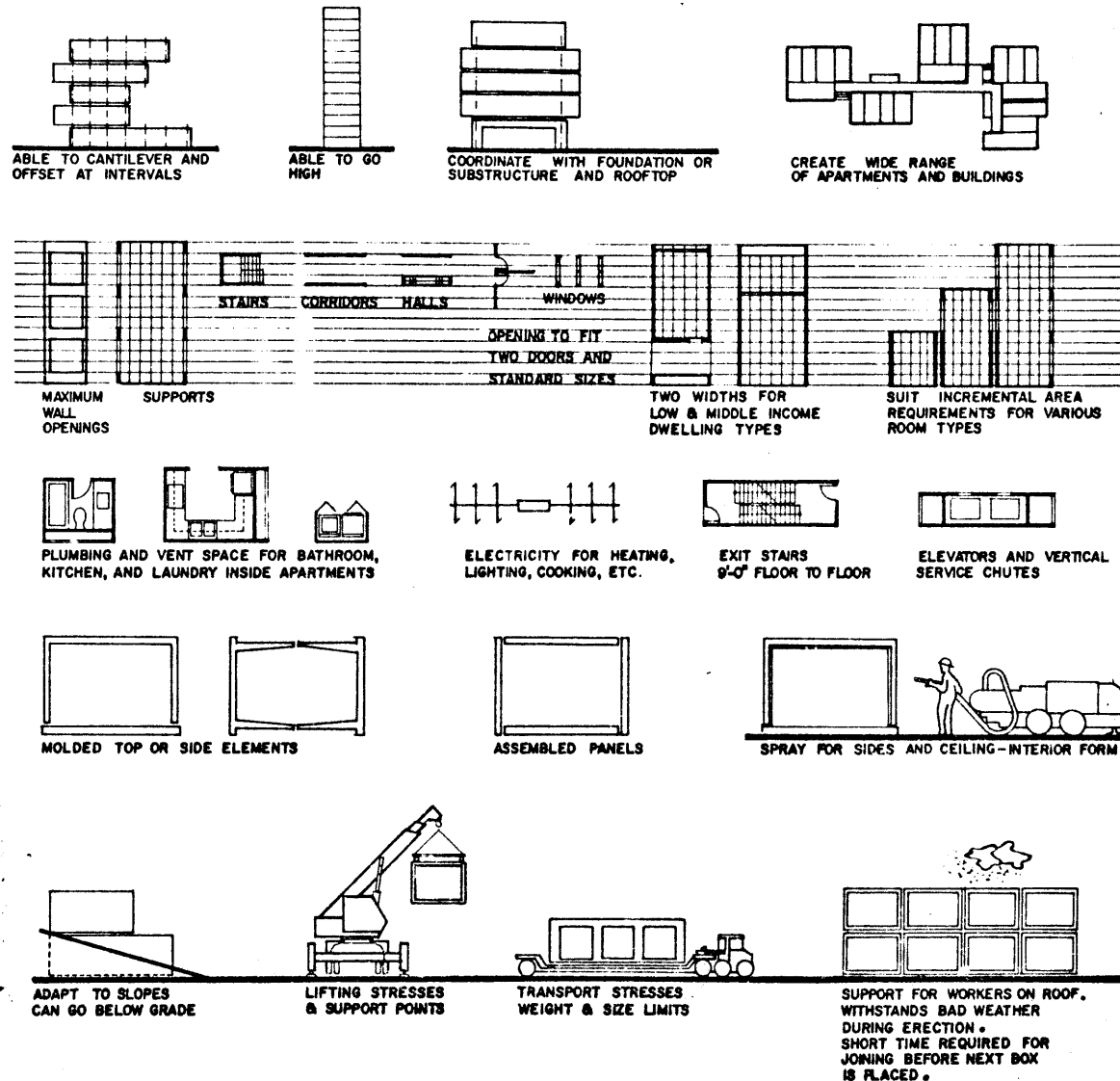
The design process, including criteria for system selection, is documented.

The intent is to determine the apartment and building types which are possible when using only box-units in combination. Each dwelling unit is comprised of 1, 2, 3, 4, or 5 boxes. The system shown uses two box widths and five box-lengths, not including optional corridors or balconies formed by cantilevering. About 60 apartment types are shown: these fall into three main categories: end-entry, side-entry, and corner-entry types. Practically all building types from high-rise buildings to single-family houses are possible using the OFFSET SYSTEM proposed.

Subsystems, components, etc. are presented. The system has several options of use by changing the type of wall and floor panels from which the box is assembled. Many design variations are possible.

Parking and shops can be included by using cast-in-place substructures or precast coordinating girders. Roof terraces and gardens are possible, and with detail changes, units can be set into hillsides. Additional roof structures can be set back 8'-8" from the building edge--or at other regular support intervals. The OFFSET SYSTEM is shown to be adaptable to a wide range of building types and site conditions.

Scope of the Thesis: Design Section



1 COORDINATING STRUCTURE TO ACHIEVE DESIRED PLANNING AND ARCHITECTURAL RESULTS.

2 DEVELOPING A 'MODULAR' BOX-UNIT WITH AS FEW MAJOR COMPONENTS AS POSSIBLE.

3 PLANNING AND DETAILING STANDARD COMPONENTS AND SUBSYSTEMS.

4 REVIEWING METHODS OF MANUFACTURING CONCRETE BOX-UNITS AND PROPOSING A SOLUTION.

5 INVESTIGATING METHODS OF TRANSPORT AND ERECTION WITH IMPLICATIONS FOR BUILDING DESIGN AND FEASIBILITY.

Introduction

When considering housing needs, some of the most important questions are:

What housing methods or 'systems' are of optimum benefit and to whom? Since society is complex, what forces are interacting to determine the actual outcome? Can we predict or formulate a policy which will fairly deal with housing and related issues?

Unfortunately, there are no easy answers to these crucial questions which should serve as a guideline in the design of a building system for housing. In the absence of clear policy, one is left to consider trends and alternatives.

Historically, an evolving trend is toward increasing industrialization of housing construction. One of the methods, representing a high degree of industrialization, is the use of box-units.

After considering many alternate types of box-unit systems for housing, including mobile homes, it was decided to limit this thesis to the study and development of box-units constructed mainly of concrete with the objective of exploring the feasibility of the method and its implications.

Concrete was selected as the material for its obvious advantages (resistant to fire, rot, vermin, and rust, economy of produc-

tion, and ease of maintenance) and in spite of its obvious disadvantages of weight and bulk, and difficulty in joining and making close tolerances.

A realistic approach is taken: that is, only products and techniques known to exist and believed to be feasible are considered in the design of the building system. Completely self-contained dwelling units such as space-capsules or bee-hive-like structural systems requiring mini-helicopters for its inhabitants are purposely avoided. Furthermore, only recent codes and regulations (BOCA, FHA, and HUD) are considered.

Attention was given to the total process of manufacturing, transportation, erection, marketing, etc.--but not enough time was available for making cost estimates that would be reliable. No guarantees or claims in favor of this system can honestly be made. Only the actual test on the marketplace in competition with existing or experimental 'systems' would produce any proof in terms of cost, performance, and consumer acceptance.

Only a 'system' for housing is developed here. An assumption is made that a market will exist for this specialized building type.

Certain characteristics of dwelling units lend themselves to the use of concrete which can be

formed into large panels or cells that can simultaneously perform the load-bearing and space-enclosing functions.

These characteristics are:

1. Relatively short spans required.
2. Large amounts of interior partitioning required in the space.
3. Comfortable room dimensions are known and limited in range.
4. Need to change partitions is minimal.
5. Area served by each utility grouping (bathroom, kitchen, stair, etc.) is small. The utility groupings are small and dispersed throughout the structure.
6. Extensive "in-floor" "in-ceiling" services can be avoided in dwellings.

When considering low- and middle-income households, the above characteristics are especially relevant. These families constitute the market segment which would most benefit from mass-produced housing units.

One of the main objectives in the design of this 'system' was to find the fewest number of components which would yield the largest number of building types and configurations. Ideally, processes can easily be changed to accommodate 'custom' design and still maintain the declared

economies of factory production and cost-control but the most economical result depends on a few versatile components.

Therefore, this thesis shows apartment plans and building types resulting from only two different widths and five different lengths of boxes, not including balconies or corridors. Even though the production process allows a wide range of dimensions, and structural details are developed to allow the use of spanning panels and kits of parts, the intent is to document what is possible when using only box-units in combination.

In order to facilitate the combining of several boxes, they had to be planned so structural supports occur at the same intervals and that provision is made for linking lines and pipes from required locations.

The problem of integrating the structural system with mechanical (HVAC and DWV) systems was compounded by a desire to keep a total depth of floor construction below 12 inches.

A method of offsetting pipes within the limits of the bathroom or kitchen cores was devised to avoid a hung ceiling throughout the box-unit and to avoid embedding utilities within the structure.

The subsystems included are:

1. Foundations
2. Electrical
3. Water Supply
4. Waste Disposal
5. Heating & Cooling Systems
6. Ventilation
7. Vents for Laundries

Components described are:

1. Roof components
2. Balconies
3. Facades, end walls
4. Bathrooms
5. Kitchens
6. Closets
7. Stairs
8. Elevators
9. Spanning panels for corridors, lobbies, laundry rooms, etc.
10. Windows and doors

Most of the subsystems are independent of the structural system. The user or client has a large choice of subsystems depending upon requirements.

Some of the larger boxes shown are likely to be too heavy for economical transport and erection when built of concrete. The weight of a typical box-unit 14 feet wide and 36'-10" long is about 35 tons--probably the heaviest feasible box. Because the weight of the concrete box-unit is its main disadvantage, limitations of trucks and cranes are investigated. Concrete mixes and various techniques to form box-units more economically are discussed.

The units can be combined to form many building types which adapt to a wide range of climate, topography, and seismic zones. The units themselves can be set directly into the ground when appropriate thickness and waterproofing is provided. They adjust to the terrain and can be modified to split-levels and to include two-level living areas.

By providing a cast-in-place substructure or precast modular elements to carry loads from above, parking and shops can be incorporated into the building.

Obviously, plans shown here are also well suited for box-units constructed of other materials and using other structural methods. The location of the supports could be retained in a suspension building, or in a post and beam framing of lightweight materials.

System Limitations

The proposed OFFSET SYSTEM is explained in Chapter VII. "Proposed Offset System: Structure" Chapter VIII. "Subsystems & Components" Chapter IX. "Apartment & Building Types".

The title may be misleading because the system works well for conventional building types, which would comprise the majority of applications, as well as for 'offset' types terraced upwards into hillsides, pyramids, or A-frame shapes or as inverted pyramid designs.

Within the limits of the plan types shown in Chapter IX. "Apartment & Building Types", the system works well. These plan types are compact yet allow good circulation within the dwelling. They are mostly suited for low and middle-income units, but the 13'-0" recommended width would still be suitable for the urban luxury market. The observation has been made, "People will stay where they are before they will go into...apartments at \$300 unless the living room is thirteen feet wide and the bedroom twelve feet wide." [1]

The 'product' is flexible to the extent that it adapts to the widest range of applications that I could anticipate. However, this approach is partly abstract, since the manufacturer must also consider other than housing uses, flexibility of the production process also, and ultimately, profitability.

Some of the limitations or disadvantages of the system are:

1. Weight remains the greatest drawback.
2. Any concrete system requires advanced materials and jointing technology and reliance upon expensive facilities and casting or molding equipment. The established concrete firms are already making products for the urban residential market with such success that little incentive exists to introduce a new product that would not necessarily expand their market.
3. Regions with a vernacular of stucco, adobe, and brick (such as the South and the Western regions of the USA) will accept a concrete system first; other regions may take some time. The system works best for the urban poor and lower middle-income groups which can not afford it.
4. Structurally, rotation of one unit upon the other at 90 degrees is not possible without custom detailing. Also, floor-to-ceiling openings are not possible unless the overall height is increased and a hung ceiling used.

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I. Industrialization

Industrialization of building means that human labor is replaced by mechanized equipment to achieve the efficiencies of mass production: more for less in less time. Capital expenditure is the key ingredient, standardization and mechanization the main characteristics.

Industrialization of building can be defined in many ways. Carlo Testa proposed the definition:

"Industrialization is a process, which by means of technological developments, organizational concepts and methods, and capital investment, tends to increase productivity and to upgrade performance." [2]

and he sets forth four forms of industrialization used today:

1. prefabrication: manufactured parts which are assembled to produce the predesigned building.
2. modular building system: interrelated components which are assembled to produce an infinite variety of buildings.
3. rationalization: the application of management techniques in all possible ways to improve production, efficiency, profits, etc.

4. on-site mechanized: low labor intensive equipment and processes are used on-site, sometimes in enclosed shelters or 'factories'.

Most buildings are 'industrialized' to some extent. The measure of industrialization is often given as the percentage of work done off-site in the factory. In this case, the mobile home is most highly industrialized, with almost all of the work completed in the factory.

Of dwellings intended for fixed foundations, MODULAR UNITS represent the most developed today.

"An advanced modular box system should 'industrialize' the major portions of the structural, mechanical, and electrical systems as well as the interior and exterior finishes. Since these activities account for 75-95% of the total construction cost in typical apartment projects, the assumption that, on the average of 75% could be industrialized leaves a reasonable allowance for site work, foundations, on-site trim out, connections and installations." [3]

The modular BOX-UNIT, is one of the most interesting types of industrialized building systems, because of the extent to which it can be finished in a factory and transported to its destination, but rationalization of

building and on-site building processes are equally valid--industrialization by factory work is not by itself a housing goal.

"The Bluebook of Major Homebuilders, 1974" places industrialized home-building into three categories:

- a** A three dimensional modular unit shipped to the site complete and installed on a permanent foundation with a minimum of on-site labor. More than one "box" may be used to make a complete living unit.
- b** A componentized packaged house shipped complete to the site, usually with major parts (trusses, wall panels, cabinets, mechanical core, etc.) fabricated to some degree in the factory--but not necessarily three dimensional. On-site labor is used, but to a lesser degree than conventional construction.
- c** A pre-cut packaged house, most of which requires some degree of on-site fabrication (trusses and minimum wall panels may be included, however). On-site labor is used to a greater extent than in "B" above, but to a lesser degree than which is considered conventional construction. [4]

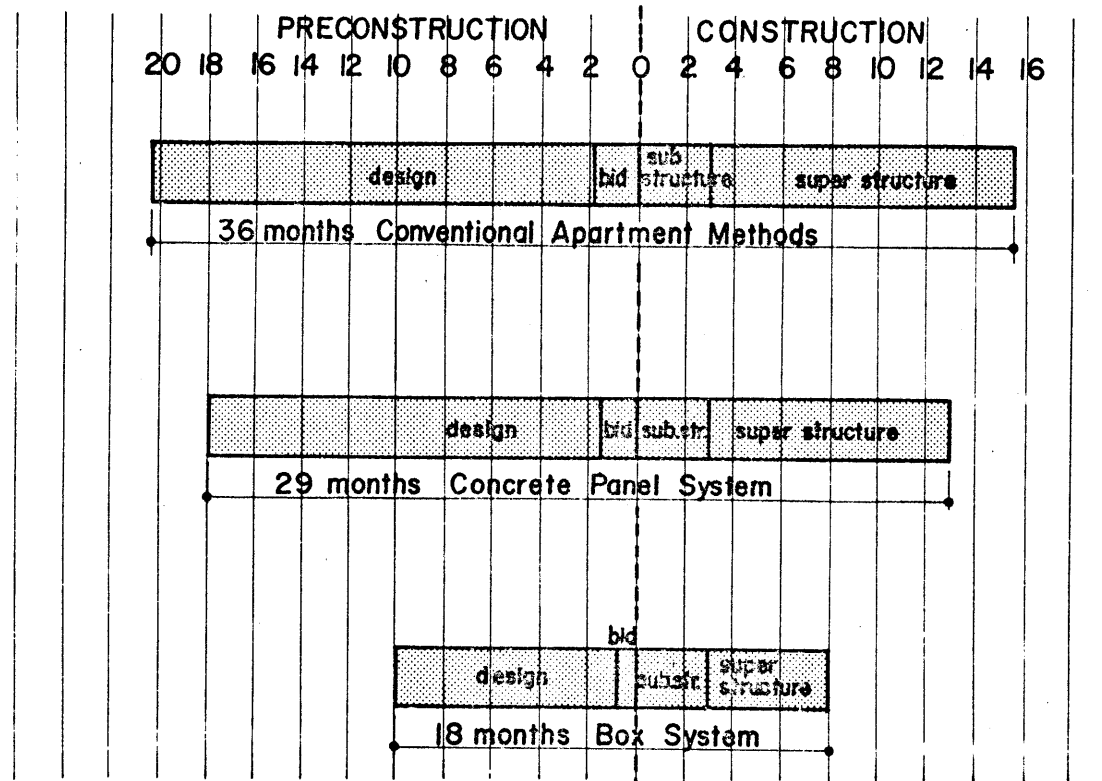
However, the advantages of using industrialized housing methods requiring a minimum of on-site labor are:

- 1. SHORTER CONSTRUCTION TIME**
Due to the pre-finished product, less dependency on weather conditions, and scheduling control. This means savings

on interest and interim financing, quicker turnover of the builder's capital, and earlier occupancy.

- 2. MORE PRODUCTIVITY PER LABOR DOLLAR**
Factory labor can be unskilled, i.e., paid low wages. Yet both unskilled and skilled labor become more productive under controlled conditions and supervision, and with using mechanized equipment. It is estimated that 250 skilled man-hours in the field will be replaced by 150 unskilled man-hours in the factory. [5]
- 3. LABOR AVAILABILITY**
Labor is not always available when and where it is wanted. A factory situation, with more steady and predictable working conditions can increase the number of persons willing to enter the housing industry. One location of work, requiring less training, less hazardous conditions, is added incentive. Access or right-to-work is easier, especially in non-union situations.
- 4. PRODUCT CONTROL**
Complex and high-quality products can be consistently produced and inspected. A single source of responsibility with service guarantees is possible. Careful design can reduce material consumption.
- 5. PURCHASING DISCOUNTS**
Since purchases can be made under annual contracts to avoid volatile price changes, protect against slow delivery, and reduce need for large inventories against contingencies, "the real economies are in purchasing, not in labor savings." [6] This

Construction Time Comparisons



Source INDUSTRIALIZED HOUSING FEASIBILITY STUDY
Herrey, A. & Little, W. MIT Press 1971
Cambridge, Mass.

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can amount to a discount on materials of 15-25% since the large industrialized housing producer can bypass the materials retailer and buy directly from the wholesaler or manufacturer.[7]

6. INDIRECT IMPLICATIONS

Less material is lost from theft, vandalism, or damage. There is less need for on-site staff and supervision. Less workmen, fewer hazards, and less risk tend to lower insurance and bonding rates. Risk of strikes and contractor defaults and delays is lessened.

7. USE OF LABOR FORCE

The housing industry can employ more people in the long-run if the product reaches a larger market, and may help to lessen seasonal fluctuations in the volume of housing production. Providing the construction work over the entire year raises employment of the average construction worker from 1,400 to 2,000 hours annually --a 43% increase.[8]

8. PERSONNEL

A missing member of an on-site crew of specialized workers can disrupt the whole team. This is less likely in a factory situation. Higher priced white-collar personnel are required however: technicians, well-trained managers, and materials specialists.

There has been much speculation about the actual cost benefit of 'industrialization.'

Since so few large projects have been built using the more advanced systems, and because firms do not want to reveal cost information--only very rough estimates can be honestly made.

According to P. A. Stone, writing in 'Building Economy', Pergamon Press, 1966, "There is no evidence either from the Continent or from Britain that the prices of the system built houses or flats are any less than those for traditionally built dwellings. . . . There is also general agreement that, as buildings, they function no better and often not as well as traditionally constructed buildings. Their attraction at the present time lies, in fact, in the possibility of using them to increase the total output of the industry." [9]

David Eacret thinks that 'factory-built housing could retail for 16-17% less than comparable units constructed in the field'.[10]

Bernard D. Stollman estimates a savings of 11% comparing conventional highrise housing with industrialized housing under favorable conditions, which is achieved from:[11]

+15%	Lower factory wage rates taking into account increased efficiency.
+ 3.75%	Reduced construction cycle
- 7.5%	Extra cost of amortizing a factory over field overhead.
<hr/> +11.0%	

"If present trends continue, a greater percentage of the total housing package will be made in the factory, especially if "field labor is continually going to increase at 10% and shop labor at 5%." [12]

No claims for success for any system can be made without considering HOW it is used. A system is only one of the tools used to achieve housing objectives and only one of the means used by management to make a profit. In this country, profitability is the ultimate yardstick to measure a system's success.

Economy--especially, total low life cost--is the key ingredient for a successful system, assuming all other criteria are met. In addition, for every construction dollar saved, there may be added savings in reduced overhead and profit, interest on loans, tax assessments, architectural and engineering fees, and other dependent cost items.

Yet, the following considerations should be kept in mind:

- a. Construction costs account for only a small proportion of all housing costs. "The cost of money, management, and taxes account for approximately 5/12, while 3/12 is the cost of the land. So 8/12 or 2/3 of the total cost to the consumer doesn't really come from the physical thing called "house itself." [13]

- b. Higher first costs may indicate higher quality or reduced life (operating and maintenance) costs.
- c. Housing demand and supply is not directly proportional to lower costs--variations in mortgage availability and rates and available land are more important. Economic contractions or expansions are initiated outside the residential sector by corporations or government. [14]
- d. Low cost units are not always the most profitable, and certainly not the most easily marketable.
- e. Persons tend to want an improved product at the same price as the old product--rather than the same product at a lower price.
- f. Industrialized housing will not cost less in the future since all costs are rising--it can only help contain costs!
- g. Reduction of costs does not necessarily mean a corresponding reduction in price to the consumer--especially if the market area cannot accommodate several competitors.

Walter Meyer-Bohe believes that the deep-seated developmental causes favoring the advance of prefabrication are:

1. Social changes tending toward abolition of class differences and equality of living habits. Rising expectations about one's housing.
2. Loss of individuality in society.
3. Concept of total planning.

His list of negative aspects includes:

1. Specialized work on an assembly line is inhuman and stunts manual skills.
2. Separation of production and assembly give rise to transportation problems and costs.
3. An industrial monopoly can arise; becoming a public charge during a depression.
4. Structural systems have not progressed.[15]

Ada Louise Huxtable presents a more critical viewpoint on industrialization:

"The gospel of industrialized housing demands revolution. It cannot work within the established system. It takes on existing practice, labor unions, custom and even life style with missionary zeal. It would require the total reorganization of the building industry into a coordinated, vertical, production-shipping-assembly format." [16]

Some other disadvantages of changing to the mass production of housing are:

1. The threat of monotony.
"Housing is a dominant aspect of our environment. Its capacity to dehumanize is evident in the endless tracts of monotonous suburban homes. As teams are organized to produce houses in quantity, therefore, it is essential that those which are concerned with social and environmental values participate." [17]
2. Organizational changes.
"As governmental and corporate agencies move into the home-building industry, the old architect/client/builder trio becomes obsolete. In its place are management teams, economists, market analysts, system analysts, efficiency experts, production specialists, manufacturers, transporters, and computer programmers!" [18] The potential of monopolies, extinction of "little" entrepreneurs, and inefficiency and inertia of bureaucracy can result.
3. Less freedom of choice.
A few large companies, once established, could lower prices to eliminate the smaller competing firms. When the competition is removed, prices could go up--and the consumer would have no choice but to accept the products offered.

The cause of recent failures in the modular housing industry are given by Alan King and James McMillan as:

1. Emphasis on production techniques rather than on marketing and consumer needs and preferences.
2. A plant too large for the market. In 1971, only one-fifth of the industry capacity was being used; in 1972, only one-third.
3. Undercapitalization: Most former producers who failed were over-optimistic about sales volume and went bankrupt trying to finance unsold finished units.
4. Inefficiency in the on-site portion of the building process. Foundations must be built, driveways paved, and utilities installed. Aside from controlling site-preparation timing and quality, the producer must schedule the erection crew to arrive at the same time as the expensive module and erection equipment. Transportation uncertainties cause this to be a weak link in the process.
5. Decline in government support for low-cost housing since 1972. Many modular producers entered the industry to produce low-cost housing under FHA 235, 236, and Farmers' Housing Administration programs. As these government funds became scarce or unavailable, producers were unable to find buyers. [19]

Information is not readily available which gives detailed reasons why firms manufacturing housing fail.

Generalized conclusions have limited value since the "industrialized housing" industry is a fragmented group with all types of products and styles of organizations.

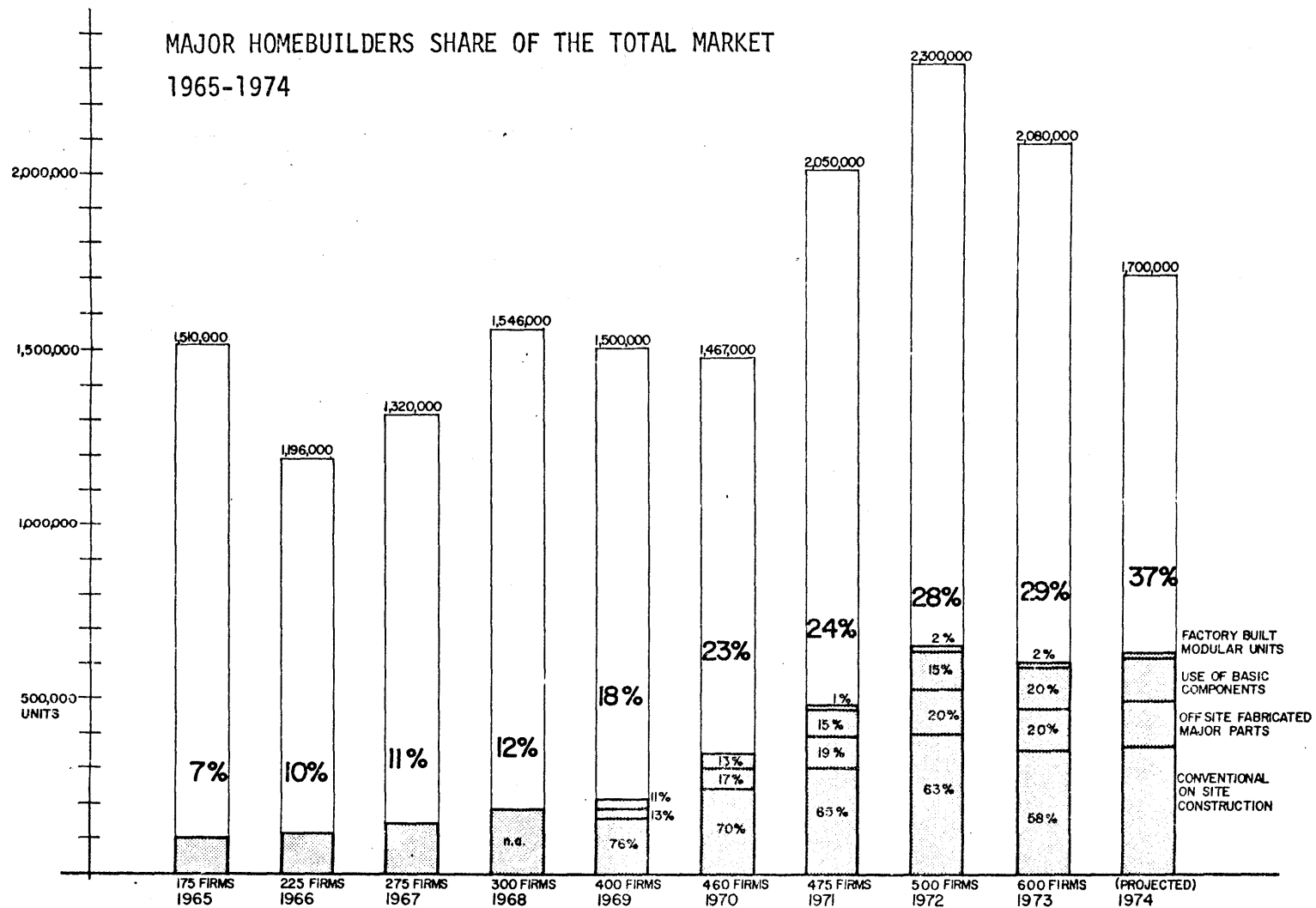
For example, the modular firms described by A. King and J. McMillan belonged to a category of producers representing only about 16% of the total 3,578 firms currently manufacturing housing. Systems builders represent 11%, Packaged or Component suppliers about 45%, and Mobile Home producers about 28% of the total number of firms listed in the DIRECTORY CENSUS, and shown on the chart opposite.

NUMBER OF FIRMS CURRENTLY MANUFACTURING HOUSING

	Change 1974 <u>July-Dec.</u>	Change <u>1971-1974</u>
67 Modular/Packaged	-4	-15
104 Modular/Mobile	14	-48
386 Modular Only	15	-71
388 Systems Builder*	31	287
659 Packaged Only	29	39
960 Components	175	NA
<u>1,014</u> Mobile Homes Only	31	371
3,578 Current Manufactured Housing Firms Listed in Manufactured Housing Newsletter's DIRECTORY CENSUS**		

*Precast, prestressed, and metal buildings

**Source: Industrialized Building,
Professional Builder, Magazine,
March, 1975, p. 117.



DEGREE OF INDUSTRIALIZATION BY MAJOR HOMEBUILDERS 1969-1974

(RESPONDING BUILDERS WITH VOLUME OF 200 UNITS OR MORE)
SOURCE: 1974 BLUEBOOK OF MAJOR HOMEBUILDERS

Adapted with permission

The gradual change in both the share of the total market claimed by major home-builders and their increasing use of prefabricated methods is shown on the chart opposite.

Most advances in prefabricated methods occur when established conventional firms change to new products and procedures. New firms also continually appear, acquire others, develop capital depth, improve management and build up marketing and distribution mechanisms.

Many authors and tradespeople emphasize the continual evolutionary process towards increasing industrialization of housing. Ups and downs in the economy, shakeups and bankruptcies will be part of the process.

James R. Hyde extends a parallel from the auto industry and points out "... few remember that, in 1921, there were 522 automobile manufacturers".

He states "Our fragmented industry seems to be becoming less and less fragmented. Architects are hiring engineers, and engineers are hiring architects. Both are becoming builders. Building firms are hiring all three. We have major capital coming into the industry. Realtors and land developers are diversifying."

"The insurance and financial institutions no longer want just a mortgage, they want ownership and participation. They want to control their money for the long range investment and see that it is properly managed."

"General contractors find that more and more work is being negotiated and not bid. Such changes are significant and will have tremendous impact. The customer wants single-point responsibility. Because of this, the contractors are having a great deal more say with reference to specifications and utilization of products. So, unless the customer and contractor can be made a part of the team for developing standards and acceptance, we can anticipate problems in marketing."

"Everyone is playing with building systems-- even government agencies which control large building segments. Mobile homes and sectionalized homes are the vogue. Low-cost housing is constantly talked about, but little action is taken because production and technology is not enough to beat the battle of inflation and the many profit centers now constituting the industry."

"Finally, as far as trends are concerned, the average builder is just tired of keeping up with this present activity because our technological developments are accelerating very rapidly. The essential question each fragmented group must answer is, 'Where do we want to go?'"[20]

COMPONENTS AND PANELS

According to a recent survey of 503 builders conducted by PROFESSIONAL BUILDER Magazine's research affiliate, the Bureau of Building Marketing Research (BBMR), use of components is way up.

Of all builders,

- 80.5% use roof trusses
- 32.0% use exterior wall panels
- 31.4% use interior wall panels
- 83.3% use manufactured kitchen cabinets
- 78.5% use prehung interior doors
- 48.5% use prefab steps or stairs

The survey also gives other detailed uses and yearly increases of component use from 1969. [21]

A trend for smaller builders to drop their own component shops and buy from others may be one of the reasons why the total number of units produced by housing manufacturing firms rose 19% from the 1st to 2nd quarter of 1974 while the number of housing starts remained unchanged at an annual rate of 1.5 Million. [22]

According to BBMR estimates, panelized/package building production hit a level of 375,000 units in 1973, went to 400,000 in 1974 and should be 450,000 units in 1975. They predict one out of four new housing units next year will be a panelized/package home. [23]

MOBILE HOMES

According to the Jan. 10, 1974 issue of Engineering News Record, one out of every three single-family houses sold in the U.S. had wheels beneath it.

Since an average mobile home costs just over \$7,000 including furniture, appliances, and carpeting, producers claim they are not in direct competition with the home-builders typical single-family house averaging \$33,000 but including land and excluding furniture. A conventional house costs \$16 per sq. ft. without land--a mobile home costs \$9 per sq. ft.

Banks are anxious to loan money for mobile homes classified as chattel with annual interest rates of about 13% over 10 years.

According to MHMA figures, mobile homes accounted for 97% of the single-family market under \$15,000 in 1972--excluding housing built by owner-builders and housing built for rent. They had 80% of the market under \$20,000 and 67% of the market under \$25,000. [24] old 28

About half of the double-wide mobile home production conforms to conventional housing codes, is placed on foundations as real property, and is financed with mortgages. About 100,000 double-wide homes were built in 1974. [25]

Mobile home shipments dropped 12.7% from the 1973 level of 567,000 units to 495,000 units. The estimated share of the market for 1975 will be below 50% for the first time in the decade. Predictions for the short term trend are shown on page 26. [26]

In order to improve sales and gain acceptance in municipalities other than rural areas where land is cheap, manufacturers are stressing the need for improved performance and appearance. Therefore, it is no surprise that mobile homes are approaching the appearance of conventional homes with 'double-wide' units and that the producers of modular or volumetric homes try to emulate the ability of the mobile home industry to keep control of costs through more efficient production in the factory.

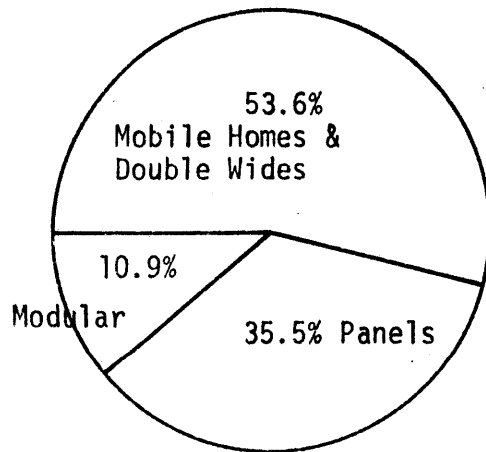
MODULAR OR VOLUMETRIC HOMES

Historically, modular housing has lacked flexibility in the marketplace. Currently 88% of the firms producing modular or 3-D volumetric homes build residential single-family or multi-family units. Another 21% offer vacation homes, and 31% market commercial modular units. The prime areas of modular home success are still in the rural areas--remote labor-poor areas where scattered lot building prevails. [27]

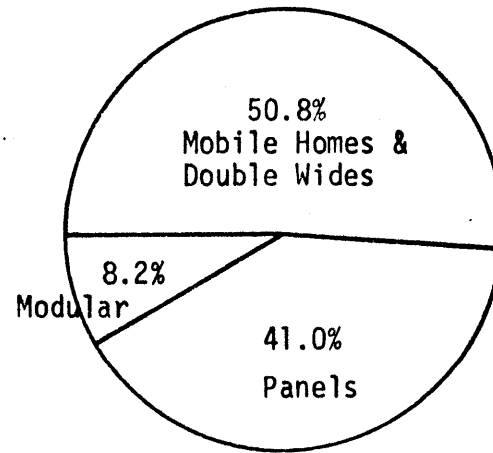
Like other forms of factory-builts, modular production is concentrated in the East-North-Central and South Atlantic Regions. 40% of all producers of modular housing are located in these regions, accounting for 48% of all modular production. [28]

According to the estimates by Professional Builder Magazine shown on page 26, their share of the total manufactured housing market is expected to decrease significantly.

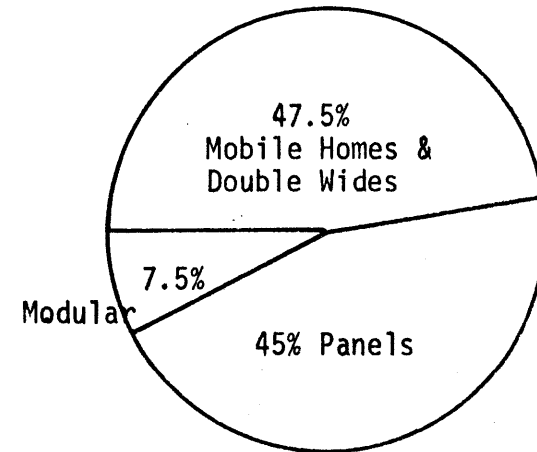
1973 1,057,000 UNITS



1974 975,000 UNITS



1975 1,000,000 UNITS



SHORT RANGE TRENDS ESTIMATED FOR PRODUCTION OF MANUFACTURED HOUSING, 1973 to 1975

Source: "Manufactured Housing Potentials and Projections for 1975"
PROFESSIONAL BUILDER MAGAZINE, November, 1974, p. 102

'Modular' production of concrete box-units is insignificant when compared to production of mobile homes or double-wides. The box-units which are produced are being used for hotels, motels, hospitals, and only a few single-family homes. (See Pages 94-99 for details of firms using concrete box-units.)

However, most of 'systems'* building is concrete--precast/prestressed firms are emerging as a big force in the construction industry--more than \$2 billion worth of work annually. Much of this market for townhouses, apartments and condominiums, resort-type construction as well as office and commercial structures.

According to Building Design and Construction Magazine, the "whole development has come along quietly until very lately. But it has already caused a considerable change in the thinking of architects, engineers, and owners. And it is bringing a new kind of 'contractor' into the picture: the concrete prestressers and precasters themselves find it easier to guarantee their products if they also have responsibility for erection with their own crew and supervisors. What's happening is that for nearly the first time in the long history of construction, a single firm is able to 'manufacture' a building from ground level to top and stand behind the product." [29]

*Systems building is loosely defined as a procedure under which all parts of a building are manufactured under factory-controlled conditions in such a way as to form a whole structure assembled either at the site out of parts or out of complete units. The building is considered as a series of packages: the structural frame, the mechanical-electrical system, the outer skin, etc., each of which must fit with the other 'packages' and which may or may not be bid separately. Most concrete firms can supply all sub-systems except the mechanical-electrical system.

TYPES OF ORGANIZATIONS

Modular housing unit producers tend to be organized in the following ways:

1. As land-developers and builders. [Vertical]
(The modular producer integrates forward into land development and building, or the land developer-builder integrates backward into modular production.)

Only a few large companies have the ability and financial resources to do this successfully, because it requires large amounts of capital in addition to skill in judging markets, timing of land purchases and in tailoring products with appropriate financing packages for local markets. There is no guarantee that the developer will be able to secure the local approvals which must precede the physical site preparation and placement of factory-built modules.

DELTONA CORP., is an example. It has located one of its two plants at one of its large retirement communities in Florida with expectations of selling both house and lot to retirees from Northern states.

NATIONAL HOMES, too, follows this strategy to an extent, selling some of its modules to in-house National Homes Construction, which in itself is

one of the nation's largest building companies with 1971 volume of about \$77 million.[30]

2. As sellers to independent agents. [Horizontal]
Producers following this strategy have generally concentrated upon two dissimilar markets: the single-family market in rural and semi-urban areas; and the multi-family public housing and governmental market.

There are several advantages to this strategy: sales are generally in areas which offer minimal resistance through local building and zoning codes; skilled construction labor is often scarce or unavailable, giving an edge to construction which minimizes on-site labor; foundation preparation can thus be generally staged to permit a plan to reach efficient production levels; erection of a unit at the site is simplified because cranes are not required in many instances and complex staging of many modules is eliminated." [31]

Many independent builder-developers in these areas do not have even a minimum ready cash (5%-10%) to place firm orders to modular producers; sometimes the

builder-developer does not have resources to pay for a unit even when delivered.

By far the largest number of successful modular producers are in this market.

"Public housing production is not the answer to the site control requirement, as the experience of STIRLING HOMEX illustrates. Stirling Homex accepted a number of contracts from public housing agencies, many calling for no progress payments but payment only when units were finally erected, and found after manufacturing the units that erection on foundations could not be completed for a variety of reasons."

"Local public housing agencies and other agencies must obtain the same local approvals as any private on-site builder and in addition follow a host of bureaucratic regulations. Many times the public visibility of a public agency makes it more vulnerable to delays and public pressures than a private developer." [32]

2. As combinations of the above. [Mixed] MODULAR HOUSING SYSTEMS illustrates the implications of this strategy best. Early in 1971, the company abandoned its efforts to sell to public housing in favor of sponsoring projects on its own. This company also builds several apartment complexes for sale to limited partnerships of investors, as well as

building a high-priced condominium project in the planned community of Reston, Va. Three other companies also build apartments with their systems and sell to others. They are all concrete-based systems operating in the high rise market: DEVELOPMENT INTERNATIONAL CORP., FOREST CITY ENTERPRISES, and BUILDING SYSTEMS. [33]

According to the NAHB publication, "Profile of the Builder and his Industry," of the home-builders producing more than 200 units in 1973,

- 83% are also active in land development
- 48% are engaged in commercial and industrial construction
- 43% are active as real estate brokers or managers
- 12% are with mobile home parks
- 8% produce component parts
- 11% are subcontractors
- 8% are mortgage bankers
- 4% are home manufacturers

Other activities include remodeling, lumber and material sales, and so forth. Because one firm may be engaged in a variety of additional activities, the total does not add up to 100%. [34]

Types of Organizations[35]

	<u>Vertical</u>	<u>Horizontal</u>	<u>Mixed</u>
Advantages	1. More efficient production capacity means higher profits.	1. Can switch from year to year to different materials, solutions. 2. Low investments	1. Sells to both outside firms or developers or owns and operates or leases its own buildings.
Disadvantages	1. Enormous investment for plant, staff and training, equipment and personnel to assemble the components. 2. Lack of flexibility. Must stick to product originally chosen. 3. Often bankrupt.	1. Control of suppliers. Reliance on other manufacturers for components and on time delivery.	
Ratio of Capital Investment/Yearly Production	0.35 If capital investment is \$100,000 yearly, production is in the order of \$285,000.	0.025 If capital investment is \$100,000 yearly, production is in the order of \$4,000,000. Use is made of the investment of other companies.	
Approximate production area/person employed. (includes president down to janitor)	170 sq. meters/person	1,850 sq. meters/person	

The large capital investment needed for plant and equipment; research, development, and testing; financing of production and inventories; and control of sites, etc., is often given as the major reason why house-building is not more industrialized.

Naturally, the higher degree of mechanization and the more efficient the manufacturing technique, the larger will be the investment required.

In order to minimize this cost, a manufacturer could consider:

- a. **AN ECONOMICAL PROCESS.** The simplest type of equipment should be used initially. Obviously, the type of product and assembly method will determine the process.
- b. **A LEASING ARRANGEMENT.** Some companies try to lease, rather than build, the factory.
- c. **AN ASSEMBLY OPERATION** The "Indiana" plan of the mobile home industry can be followed: components produced by others are assembled by the many suppliers who should be nearby. (Advocates of this type of organization favor the industry-wide modular coordination of parts referred to as the "open" system.)
- d. **STARTING SMALL** "The industrial giants seemed to think factory-built housing

could match the success of the mass-produced automobile, but I think they forgot that Henry Ford started as a one-man operation in a Michigan barn," states Fritz Stucky, designer and developer of the VARIEL system in Switzerland who started with three wood modules produced during a winter in a Swiss carpenter's workshop in 1956. [36] His Variel system has grown to six factories in four European countries that produced 6,948 modules for a sales volume of \$52 million in 1972.

In sharp contrast to the above approach, are opinions that a profitable venture can result only from complete control of the entire house-building and developing cycle.

Advocates of vertical organization that control of building sites must be maintained if the venture is going to make any sense at all. It is important that production be kept continuous, and since storing large number of units is impractical, the best place to put them is in place. After all, this is what average developers do--present a completely finished product to the consumer on its site.

If the industrialized housing manufacturer does not control the sites directly, he has to rely on many small builders, or a few large ones.

Obviously, an organization that seeks to control land acquisition must have an entirely different organizational structure and vastly different capital needs.

An established firm outside the United States projected an investment for 1971 "which called for six plants with a total of \$15 million investment plus \$100 million investment in subdivision land, model homes, and marketing organization". [37]

The MIT Study [38] suggests that the total investment for only the production facility of a concrete box system would be at least \$5,500,000. The experience of the Russians is that a box-unit facility costs about 15% more than that required for production of concrete panels. [39]

According to the MIT Study, "Most of the companies in the manufactured box business probably have investments of less than \$2 million. If they can maintain sales volumes of about 250,000 to 500,000 sq.ft. of floor area per year, they should be able to compete profitably with conventional construction. A company planning to invest from \$3 to \$6 million must sell in the order of 500,000 to 1,000,000 sq.ft. per year to remain profitably competitive. Finally, any company planning to invest more than \$10 million...should have solid plans for achieving a market greater than 1,000,000 sq. ft. per year." [40]

Large-scale manufacturing corporations with the necessary skills and capital are cautious about entering the box-unit field because better profits with less risk and effort can be made elsewhere.

1. Start-up costs and investments are high; To assure success in the venture, control of the market is necessary. This becomes difficult in terms of capital requirements and in terms of management versatility. Most large firms have not built up the type of expertise or organization to deal with this.
2. Large building materials producers tend to create 'competitive' situations with existing markets.
3. Time lag between investment and return is too long for the dividend-oriented manufacturing industry.
4. As a native commodity, use of cheap foreign labor characterizing so much of our consumer products is not made.
5. Competition is fierce from small, numerous and flexible developers with experience.

6. Large corporations soon realize that real profits in house-building are not in the house or structure itself. Large firms can acquire land at wholesale prices, develop it, and retail the lots. The type of construction method or system used is of only minor relative importance. For large firms, land development and new commercial development is more profitable than systems development.
7. Large corporations can invest in existing production facilities and firms indirectly.

The necessary conditions to support large capital investment and large scale production of identical parts are:

1. A significant price advantage over substitutes.
2. Inability of current production to meet existing demand at current prices..
3. A non-differentiated market where some price advantages are possible over current production methods.
4. The clear superiority of the new product in the eyes of the customer or consumer.

II. Considerations & Constraints

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FINANCING

The condition of the industrialized housing industry at this point can be no better than that of the housing industry as a whole. This is especially true with regard to financing.

Financing is crucial to both producer and consumer--when loans or mortgages are difficult to obtain or when interest rates are high, sales are few.

According to Eacret, over half of all families are ineligible for mortgage financing, using the credit rule applied by most private mortgage lending institutions. This rule is that a family can afford a residence costing about 2.5 X its annual income before taxes, which translates to about 25% of personal income being spent for loan principle, interest, insurance, taxes, and maintenance on a residence.[41]

The depressing impact of the present economic crisis, coupled with the inadequacy of the present system of housing finance, has driven housing starts below an annual rate of one million, less than half the rate of more than two million starts reached 18 months ago. In addition, unemployment in the construction industry has soared to 15%, more than twice the current national figure for the entire work force.

A recent study at MIT's School of Management urges reform of the present home financing

method, by replacing the present fixed rate of interest and periodic payment with a "price-level adjusted mortgage" which would carry an inflation-fee interest rate at the outset--currently about 3% compared with the average going rate of about 10%. The monthly payment would increase over the life of the mortgage as the cost of living increased. (This would bring home ownership within reach of households who have been priced out of the market by inflation, and might pave the way for the removal of ceilings on deposit interest rates.[42]

Most modular producers could not collect construction draws until the box is physically placed on a foundation--at which point a draw of 90% of selling price is generally allowable. The additional 10% is paid when construction and site work have been completed and accepted.

Thus, the typical cash flow for a modular builder is exactly opposite for the on-site builder who can collect materials advances and as construction materials and labor are placed on the site. The net result is that any major order to a modular builder that does not provide some supplemental inventory financing arrangement or some system of payment for construction work in the factory can literally bankrupt the modular producer.[43]

CODES

Building codes are a series of standards and specifications designed to establish minimum safeguards in the construction of buildings, to protect persons in them from fire and other hazards, and to further protect the health and safety of the public.

The problem is not that they exist, but that there are so many of them and they are not consistent. Some codes act to protect local tradesmen, producers, suppliers, or even local inspectors and officials.

Any manufacturer operates under at least one, and probably two of the three regional codes: ICBO, BOCA, or SBCC.* Local governments (8,344), states (50) and federal agencies (35) including FHA, PUD, etc., are also concerned with regulations and standards.[44]

Codes can add \$1.00 to \$3.00 per square foot to housing costs because the system producer must meet all the different code requirements.[45]

*ICBO = International Conference of Building Officials, BOCA = Building Officials and Code Administrators, and SBCC = Southern Building Code Conference.

In 1969, California enacted a factory-built housing law which permitted manufacturers to regard the state as a single market for a model series, instead of having to tailor units to local laws. In 1970, Washington enacted a similar law which is reprinted in MIT's "Housing Feasibility Study." [46]

The BOCA Basic Building Code used in 1500 jurisdictions has just been updated for manufactured housing. A new "Basic Industrialized Dwelling Code" or "BIDC" was formally adopted by the Building Officials and Code Administrators International, Inc., on January 1, 1975 and will probably be adopted for use in Virginia, Connecticut, Massachusetts, Maine, Maryland, Michigan, Pennsylvania, and Rhode Island.[47]

As with other BOCA codes, the local building official will enforce its administration. He will receive applications, issue permits, and other orders. BOCA's own inspection agents will visit plants, evaluate samples, and issue labels for approval. The estimated charge for these services is \$15 to \$20 per unit. The BOCA code label serves as a logical basis for reciprocity of acceptance from one state to another. [48]

LABOR RELATIONS

The worker is confronted with hazardous and piece-meal work and uncertainty of employment. His life's workspan is shorter than the white-collar counterpart since it is dependent upon his physical condition. His high hourly wage should reflect these factors --and often does if he is represented by a union.

Nevertheless, unionized labor (accounting for 80% of all construction workers) is usually blamed for high housing costs out of proportion to the other factors such as price-fixing by suppliers and carriers, use of inferior materials, inflated insurance and interest rates, rising speculative land costs, and increasing taxes.

Advocates of union reform want to abolish the hiring hall, reform the apprenticeship program, create efficient arbitrating bodies, impose sanctions against violence and destruction, and eliminate the Davis-Bacon Law.

According to the MIT Study[49] unions have little interest in halting introduction of building systems. Their interest is in controlling the work to be done by union members under conditions established by collective bargaining contracts. Unionized on-site workers, especially in urban areas, are able to reject products from non-union shops.

Traditionally, most single-family construction is non-union. The wage rate of non-union factories is about \$1.00/man-hour less than in a unionized plant.[50]

A manufacturer for the high-rise market may have to accept a union shop and negotiate the arrangement of work. Several different types of contracts have been tried:

1. In 1969, Stirling Homex signed a labor agreement calling for the United Brotherhood of Joiners and Carpenters to furnish competent journeymen nationwide for the site erection of the company's housing modules.[51]
2. With industrial unions such as Wickes Corp. by the United Auto Workers, Integrated Modular Systems by the Steelworkers, and San Vel by the Teamsters.[52]
3. With a merger of trades, such as the Tri-Union Carpenters, Plumbers, and Electricians.

MARKETING AND MANAGEMENT

"For systems and precoordination to work industrywide, it is essential that we start with the customer." [53]

Instead of focusing on the needs of the marketplace and the development of marketing capabilities, most management teams have directed their efforts toward the firm's production capabilities. Instead of asking, "What type of house does the prospective homeowner want? and Can I profitably manufacture and market this unit? most firms concentrate on deciding what they can produce using their existing plants and production skills. The result has all too frequently been a modular unit with no advantage over the conventional home and one which is perceived to be inferior by homeowners and prospective buyers." [54]

Consumer surveys indicate that the public thinks of modulares as standardized boxes and associates them with public or low-cost housing. As a result, they are designed to look as much like the conventional home as possible, and the builder prefers not to advertise the fact that they are prefabricated or modular homes.

Consumer preference testing is not easily done, unless a great deal of time and specific questions are available:

1. What price level will consumers accept unfamiliar design? (The mobile home, a strange shelter, was accepted because it

had, among other attributes, the right price tag.)

2. Will the consumer accept wall and ceiling that do not meet at a right angle? (As appears on some cast concrete systems such as HABSystem.)
3. Will they accept visible joint in the walls and ceiling? (As the Diskin system of ring-cells.)
4. Will they accept the minimum allowed 7'-8" ceiling or be willing to pay more for 8'-0" or 8'-6"?
5. Will they accept rooms with no ceiling lighting fixtures? (As is common with most concrete panel construction in low-income projects.)

Marketing encompasses many sales techniques, including:

1. Use of local builders as distributors.
2. Home warranties or guarantees.
3. Helping Builder obtain permits.
4. Advertising.
5. Aggregation of markets to assure continuous sales:

- a. Seeking government support.
- b. Seeking support of other funded groups:
 - (1) Churches
 - (2) Unions and Service or Trade Organizations
- c. Alliances with land developers and contractors.
- d. Attempting to collect large quantities of small customers so as to be able to assure orders for housing before production begins. [55]

Building systems producers stress their management skills almost as much as their product:

For example, a brochure from DESCON/CONCORDIA states "The knowledge and talent of a team possessing a wide range of disciplines are implicit in the creation of a management system for the construction industry," and "the system applies available technology to organize the process of analyzing problems and evolving solution designed to achieve maximum results." [56]

Administration, Design, and Production are brought together under Project control.

ECHO supporting services include:

1. Consultation with the architects and engineers on the most advantageous uses of the system.
2. Obtaining preliminary estimates and building schedules from licenses ECHO manufacturers in the project area.
3. Coordinating all schedules for subsystems to the project from manufacturers of ECHO components in the project area.
4. Obtaining final pricing and manufacturing schedules for start of the project.
5. Coordinating the issuance and approval of shop drawings for subsystem manufacturers.
6. Performing initial quality control inspections for the architect on receipt of subsystems from the manufacturers.
7. Performing final quality inspection prior to substantial completion.
8. Performing general architectural type supervision for that portion of a building project that is manufactured by ECHO DEVELOPED INDUSTRIALIZED CONSTRUCTION METHODS from licensed manufacturers.

"Owners and developers desiring to use the Echo Module System enter into a contractual

agreement with the regional ECHO entity. This agreement grants the use of the system and the aforementioned supporting services of an ECHO representative on a per project basis."

"Owners and developers using the ECHO Module System enter into purchasing contracts exclusively between them and the Qualified Manufacturers, as shown on the graphs, for that portion of a project using industrialized construction methods licensed by ECHO."

The ECHO GROUP, INC. uses a proprietary computer aided design system--claimed to be the only one of its kind available anywhere on a time-sharing basis. ECHOPLAN is a series of computer programs which automatically produce much of the detailed drawings and cost data required to plan a building using the ECHO Building System. These programs are available on a time-sharing basis through national computer centers. As an alternative, participating architects can lease a teletypewriter with plotting capabilities for use in their own office for a nominal monthly fee.

The total time-in-process is about 8-10 hours for the average building. As a result, all the data required to assemble detailed drawings, specifications, and quantity surveys for the building is fully documented.

The owner, in effect, buys a completely erected structure at a predetermined occupancy date and cost."[57]

If the system is simple, and has nothing that qualifies it as a proprietary system, the company that wants to sponsor it would be wise to ally itself with a qualified reputable concrete manufacturer. Continued availability, dependability, and a good management will be the essential ingredients for a profitable business.

DESIGN PROBLEMS

The choice of the proper system is one of the most, if not the most, important decision the promoter can make. This choice will have been made under all aspects of investment required, market acceptability, code and standard compliance, price range of final product, market demand, etc.

Choosing the proper degree of technology best suited to the country's economic situation and utilization of the labor force is beyond the scope of this thesis. There are arguments against methods which require extensive capital investment, concentration of production in a few large companies, and fewer workers required. On the other hand, the highly industrialized mobile home industry has succeeded in producing a low cost dwelling within the budget of the average working man.

The appeal of the industrialized product must be coupled with the appeal of home ownership and the desire for a small piece of land or garden. The industrialized unit need not be stereotyped. Although this thesis explores one approach to design by having as few as possible components used in combination to produce a wide variety of structures, it is also possible to design the production facility to adapt to a wide range of shapes and sizes. For example, stair cores, balconies, flower boxes, special forms for on-site columns, and substructures require special consideration that only a flexible facility can handle. Moreover, one facility need not produce the entire range of products needed--subcontracts can be let for appliances, kitchens, bathroom cores, whenever it is more economical to do so.

The industrialization of building construction creates a new situation: the design must be studied as an integral part of the manufacturing and assembly processes. For example, all inserts must be detailed and all working drawings completed before construction of molds can begin. Subsequent changes are costly and mistakes have larger implications.

The Greater London Council (GLC) has abandoned use of the Balency concrete panel system for Thamesmead, a new town 9 miles from London. The pace of all construction in the town has slowed to such an extent that conventional construction has become more economical. [58]

The architect, Alan Comrie Smith, and the prime contractor, Holland & Hannen and Cubitts, agree that the system had other drawbacks, too. The system required workers who are trained in that particular type of construction. Panels were damaged when lifted into place, but poorly repaired, causing uneven joining which in turn allowed rain to enter.

The problem involved a detail of vertical seals at the corners of the structures. There is a triangular groove that runs along the interior of the corner, and this must be continuous for the full height of the building so that any water that penetrates the seal will be caught in the triangular groove and drain to the bottom. When the edges were chipped away, the groove ceased to be continuous, and there was a build-up of water. [59]

This problem may not occur with concrete box-units, but it is an example of attention that must be paid to careful detailing of any method of building with large components. Often, these problems do not become apparent until actual structures have been built and in use for several years.

CHANGING ROLES

The complexities of "industrialization," the growing realization of the value and need for "environmental" planning through proper site utilization, etc., only can open up new opportunities. Tedious work and repetitious work may give way to more conceptual design and area-function studies, with much emphasis on site planning. In the long run, waste of effort from designing each building from "scratch" is reduced. The activities of each participant must be coordinated by one designated as responsible for final decisions. Designers, structural engineers, electrical and acoustical consultants, manufacturers, contractors, etc., must be brought into the design at the very earliest stages. Although each must have skill in his particular discipline, each must be able to define and present the information upon which others can make a decision. Needs of the entire design and production cycle will evolve from regular sessions and reports.

Crucial to the success of the project will be a system of handling information and decision-making and control. (This is also true in non-industrial systems, but especially critical in large projects characteristic of industrialized systems.) The sponsor of the system will find that skilled personnel, computer operators, construction or project managers, etc. are not only hard to find--they are expensive--so overhead may be high.

Of 36 firms producing manufactured housing of all types which answered my questionnaire, 26 or 72.2% use architects as consultants, 18 or 50% had architects as clients, and 12 or 33.3% had architect-employees. Only 5 of the 22 producers of 3-D modular units did not use architects as consultants.

"One problem has been the inability of architects and engineers to relate the process of industrialization to building design. Their principal failure is their reluctance to stay within the design disciplines required to obtain maximum cost-savings through systems buildings. For example, one UDC Building constructed with a precast building panel was so designed that each wall panel at the gable ends had to be treated as a custom-made element. In another building there were 188 different types of floor components, each type requiring a different size configuration. Of that unusually large number, 78 types required only one to three individual castings." [60]

PUBLIC POLICY AND RECENT ACTIVITY

The industrialized housing manufacturer has to take careful account of all aspects of the housing industry affected by local, state, and federal governments. This is a lengthy and involved process, especially since policies and legislation are constantly changing.

Basically, there are two main types of opinion:

1. Those who believe government should take a more active role in providing low-cost housing, and
2. Those who believe an un-fettered market (with open competition) should prevail.

The present situation lies somewhere in between.

Traditional builders (and mobile home producers) have reason to complain if subsidies are granted to a select few who could qualify for a certain type or amount of aid to advance "industrialization of housing."

It is difficult, if not impossible, to try to make recommendations without knowing the exact content and consequence of each piece of proposed legislation.

In the final analysis, those groups which can exert the most influence through lobbying, campaign contributions, and shaping public opinion to form voter blocs are going to prevail.

One such group is the newly formed (January 21, 1975) National Construction Industry Council (NCIC) to be composed of national associations representing architects and engineers, contractors, suppliers and educators which has intentions "to work with the Federal Government in the public interest." One of the issues the NCIC will consider is the need for establishment of an Office of Construction (OOC) in the executive branch of the Federal Government. [61]

The Council now has 31 member groups, including the American Institute of Architects and the American Society of Civil Engineers. It plans to meet the third Thursday of each third month and to report periodically to the President and Congress and report annually on public funds or jobs. Although the main objective is to present a unified front when dealing with the federal government, there are internal conflicts over labor related issues. [62]

OPERATION BREAKTHROUGH, begun in 1965, was an attempt to encourage technology that would produce housing faster and cheaper--but it became bogged down in poor organization, red-tape, no marketing input, no follow-through plan, and no continuing budget. In the end it cost \$137 million with dubious results, including making many persons extremely cynical about "industrialization of housing." [63]

In August, 1974, the OMNIBUS HOUSING BILL became Public Law 93-383. A series of eight major HUD programs, including urban renewal and open space acquisition and development, will be eliminated. Some of the major items:

1. \$8.3 billion of the \$11.1 budget will go as "block grants" to urban areas over a 3-year period.
2. Authorizes HUD to conduct solar energy projects.
3. Permits HUD to set national standards for mobile home construction and materials.
4. Raises mortgage interest rates and lowers down-payment requirements for FHA-guaranteed housing.
5. Makes special provisions for housing for the elderly.

With regard to building research, the bill also establishes the National Institute of Building Sciences with a \$5 million annual authorization. The Law requires that the NIBS be set up with the help of the National Academy of Engineering, the National Academy of Sciences, and the National Research Council. A charter has yet to be drafted and an executive council of 15-21 members chosen by the White House from a list prepared at HUD. As a quasi-governmental agency with limited funding and power, it may not be able to achieve the long-sought momentum toward a national building code. [64]

The National Commission on Fire Prevention and Control was also established by Congress in 1974. [65]

It joins the Federal Trade Commission (which exposed the plastics industry and independent testing labs as misrepresenting burning characteristics of plastics) and the CONSUMER PRODUCT SAFETY COMMISSION (which sets standards on architectural glass, aluminum wiring, and other products for the home) in influencing housing materials.

Technical criteria for conservation of energy developed by the NATIONAL BUREAU OF STANDARDS has been referred to the AMERICAN SOCIETY OF HEATING, REFRIGERATION AND AIR-CONDITIONING ENGINEERS.

The ASHRAE is expected to produce a revised standard for state and local building codes embracing everything from wall thickness and window area to heating and lighting systems. These criteria are to be developed from guidelines published by the FEDERAL ENERGY ADMINISTRATION (FEA) and the COMMERCE DEPARTMENT. [66]

Although federal land use planning legislation was defeated in the 93rd Congress--by a narrow margin--HUD officials may prefer to allocate community development program funds in the direction of carefully planned high density cluster development. [67]

This view is reinforced by a recent study by the Real Estate Research Corporation, Chicago, for HUD; The Council on Environmental Quality; and The Environmental Protection Agency. Results of the study show that:

"Total construction costs for a high density (multi-family) community are 56% of those for the conventional low-density (detached house) sprawl development, resulting in a saving of \$227.5 million for a community of 33,000 people with 10,000 dwelling units. Savings in land cost amount to 43% with savings of 40% for streets and 63% for utilities."

"Operating and maintenance costs in the high-density community are estimated to be approximately \$2 million (11% less per year than the low-density sprawl development, due

largely to less road and utility pipe links and reduced gas and electric consumption.) Public operating costs may be reduced 73%.

"The high-density planned development model was composed of 70% apartments, 20% attached townhouses, and 10% detached homes. Reduced auto travel in the high-density planned community could reduce air pollution from 20% to 30% and the related energy expenditure by 8% to 14%, the researchers concluded. [68]

In June, 1974, the U.S. signed a joint agreement with the U.S.S.R. for increased joint efforts in energy research, housing construction technology, new towns development and earthquake science. In the housing area, new methods and materials will be evaluated, criteria will be developed for water, waste, and heating services, and studies will be made of construction in extreme climates and soil conditions. A group of U.S. housing experts was sent to examine Russian development of new towns in July, 1974. [69]

PUBLIC AND PRIVATE RESEARCH

Some of the governmental agencies involved with research with regard to housing and other construction are:

Department of Housing and Urban Development (HUD)

National Institute of Building Sciences (NIBS)

U.S. Department of Commerce

National Commission on Fire Prevention and Control

Federal Trade Commission

National Bureau of Standards

Federal Energy Administration

Council on Environmental Quality

The Environmental Protection Agency

Federal Housing Administration

Many trade organizations such as the NATIONAL ASSOCIATION OF HOMEBUILDERS (NAHB) and the MOBILE HOMES MANUFACTURERS ASSOCIATION (MHMA) provide statistics, surveys, and other valuable information as well as serving their members.

According to the "Industrial Research Laboratories of the United States, 13th Edition, 1970", there are 5,237 non-governmental labs devoted to fundamental and applied research, representing 3,115 organizations. The labs, concerned with research related to the scope of this paper, are: [70]

Construction products and materials	54
Systems engineering	27
Structures	17
Urban studies	12
General construction	5
Concrete	23

As is well known, many architects and engineers are developing 'systems' and patenting features of construction.

One example is German architect Rudolf Doernach, who "spent more than \$4 million on his 'space unit' project--funds from private industry, government sources, and his own pocket". [71]

There are other examples too numerous to be mentioned, including work done in universities.

The CONSTRUCTION RESEARCH COUNCIL (CRC) has just been established as a research corporation to assist private and public building owners in fostering wide-spread use of pre-engineered and pre-coordinated building components. [72]

Initial efforts will be in the development of standard sub-system performance specifications for such components as wall, ceiling, floor, and mechanical systems, so that longer production runs can be started and competition among suppliers created. The research corporation will attempt to promote the use of subsystems for commercial, industrial, and multi-unit residential structures.

The organization began after a study prepared by the Federal Construction Council, a BRAB division. BRAB and the parent NATIONAL ACADEMY OF SCIENCES--NATIONAL ACADEMY OF ENGINEERING are offering assistance for the establishment of CRC.

Officials hope to have 100 owner-user members with a annual fee of \$5,000. At the present time, the Construction Research Council has eight members.

Firms or entities represented are:

General Motors Corporation,
Argonaut Realty Division
(Ivan E. Packard, Chief Engineer
and chairman of CRC)

Sears, Roebuck & Co.

City of Boston, PFD

American Telephone & Telegraph

General Services Administration

Office of Construction, Veterans'
Administration

IBM, Real Estate and Construction
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III. Design Parameters Outline

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BASIC SYSTEM CATEGORIES

ON-SITE OR PROCESS METHODS

1. "Lift-slab".
2. Push-up construction.
3. Spray Applications:
 - a. Concrete sprayed on formwork or inflated forms.
 - b. Plastics.
4. Automatic laying and welding of polystyrene blocks (Dow Chemical Shell House).
5. Sliding or Rolling Forms: Continuous 24-hour forming (in-concrete)--no joints. Also "slip-form."
6. Conventional on-site construction with prefab and re-useable formwork; or pre-cut pieces.
 - a. Moveable scaffolding and forms for "flatplate."
 - b. Waffle slabs with pans, hollow tile, fillers, etc.
 - c. Cast-in-place beams, ribs, tees, etc.
7. Permanent shuttering; use of prefab outer forms into which structural concrete is poured.
8. Entire building designed to act as structural entity:
 - a. Building conceived as "tube."
 - b. Building exterior walls as trusses (also = a).
 - c. Staggered truss design
 - d. Partial load-bearing (L-shaped columns form corners of building)
 - e. Space frames.
 - f. Interstitial trusses form mechanical floors.
 - g. Tension structures, suspension structures.
 - h. Shell structures.
 - i. Folded plate.
 - j. Hinged arches.
9. Post-tensioning.
10. Underground application.

3-D VOLUMETRIC UNITS (MODULES)

- a. Complete unit in one unit, such as a mobile home.
- b. Sectionals: two or more boxes fit together to form unit, or clustered around patios, etc.
- c. Core types: Central core contains mechanical and utility functions; serves as attachment for panels, etc.

All have possibility to be stacked for multi-level dwellings, or be supported by independent skeleton structures.

PANEL SYSTEMS

- a. Flat panels: Can have services integral with the panel
 - 1. Welded joints covered with grout such as "Igeco."
 - 2. Tilt-up panels joined at site.
 - 3. Categorize by materials and methods.
 - 4. Sub-categorize by erection type, i.e., joint types.

b. T-panels:

- 1. Stable elements don't need shoring, such as "LaCrete."
- 2. Floors are slabs or flat panels.

c. U-panels:

- 1. Shaped stable elements containing furnishings; can be combined to form columns, wall corners, etc.

Flat panels have possibility to be pre-joined into 3-D Modules.

PARTIAL 3-D SLICES

- a. Geometric shapes from partial 3-D modules used for roofs, etc., contain moment connections for easy combinations.
- b. Large units can be stacked in alternate "checkerboard" sequence, such as the "Shelley" system.

COMPONENTS

- a. Made-to-order components
- b. In-stock components (typical 2 x 4 wood studs, standard lengths of hollow-core plank, etc.).

CRITERIA FOR SYSTEM SELECTION

1. COST

- a. First Costs
- b. Operating and Maintenance Costs
- c. Funding (government subsidies, tax write-offs, etc.), i.e., costs to all parties involves vs. benefits and value.

2. PERFORMANCE

- a. Aesthetic--includes client and community acceptance.
- b. Functional--meets user requirements for space, comfort, safety, security, privacy, convenience, health, and other biological and psychological needs. That is, the system must be capable of manipulation towards these ends.
- c. Adaptability--to different regional and cultural differences including climate, site, landscape, "life-styles" influenced by political and other traditions. That is, ability to suit a wide category of users and conditions --perhaps with use of interchangeable components.

- d. Flexibility--adaptability to change can be achieved by changing dwellings, provision of enough rooms or space within unit for re-grouping or changing use of rooms, easily moved partitions (assumes enough space reserves, space to store partitions easily obtained, acoustical and fastening problems can be overcome).
- e. Desirability--type of system user would choose if unlimited alternates were available in same price range.

3. TIME REQUIRED FOR PROJECT

Depends upon financial and market conditions, some operations are time-critical; others are not. Look into:

- a. System Availability.
- b. Labor Time Required; Labor Availability.
- c. Transportation Feasibility and Scheduling.

d. Total Time Spectrum as Compared with Other Systems:

1. Zoning Approval Time
2. Financing Approval Time
3. Planning and Design Phase
4. Implications for Site or Fast-Track Work
5. Ordering and Warehousing Implications
6. Preparation of Bids
7. "Red-Tape"--Government Agencies
8. Construction
9. Marketing
10. Other

4. RISK

What are the incentives for choosing one system over another? What are risks vs. benefits and how are these distributed to the architect, client, builder, taxpayers, users, manufacturers, workers, contractors, and other parties involved?

OUTLINE FOR PERFORMANCE CHARACTERISTICS

STRUCTURE

1. Wall compression
2. Wall/floor joint compression
3. Floor bending strength & deflection
4. Roof/ceiling strength & deflection
5. Floor creep
6. Floor damping
7. Fatigue
8. Eccentricity of joints
9. Tolerances

ACOUSTICAL

1. Sound transmission
2. Impact
3. Joints (doors, windows, w.c., etc.)

FIRESAFETY

1. Rating (time to failure)
2. Walls--Ceiling--Floor
3. Flame spread
4. Smoke

THERMAL AND VENTILATING STANDARDS

1. Solid walls: surface temp. on inside walls
2. Window assemblies: surface temp. on glass

3. Air temperature
4. Humidity
5. Air purity: pollen, smoke, odors, etc.
6. Amount of fresh air changes

ENERGY USE STANDARDS

1. Energy consumption per sq. ft.
2. Material consumption
3. Labor consumption

SPECIAL CODE REQUIREMENTS

Weathering Characteristics
Surface Durability
Maintenance
Resistance to Deterioration
Ability to Alter
Support for Hanging Equipment

PLANNING CONSIDERATIONS

UNIT FLEXIBILITY

- a. Ease with which different plans can be achieved for each apartment type with a relatively low number of basic components.
 - 0-bedroom
 - 1-bedroom
 - 2-bedroom
 - 3-bedroom
 - 4-bedroom
 - 5-bedroom
- b. Number of basic apartment types possible.
- c. Are two-story apartments possible?
- d. Are split-level apartments possible?
- e. Can partitions be moved after completion? (Demountability)
- f. Is good proportionality of living spaces to bedroom area possible?
- g. Suitable for uses other than housings?
- h. Provision for expansion of unit?
- i. Relationship of unit to exterior spaces, e.g., balconies, sun control.

UNIT CHARACTERISTICS

- a. Minimum floor-to-floor height.
- b. Minimum floor-to-floor height with openings floor to ceiling.
- c. Frequency of columns: freestanding or interruptions on wall surfaces.
- d. Wall-opening size restrictions.
- e. Ratio of area of envelope to area of dwelling unit.
- f. Visibility of joints; frequency of joints.
- g. Condition of intersection of walls and ceiling and walls and floor.
- h. Ceiling fixtures possible?
- i. Ease of access to utilities for repair or replacement.
- j. Sound (or impact) reduction between units.

ASSEMBLY CHARACTERISTICS

- a. Weather-proof and soil-resistant.
- b. Support for workmen during assembly.
- c. Safety of erection for workers.
- d. Time for completion of building types.
- e. Ease of connection services between modules: horizontally and vertically.
- f. Ease of fireproofing and finishing joints between modules.
- g. Ease of applying roofing materials.
- h. Ease of scheduling work activities.
- i. Ability to be transported and erected without damage. Ease of repair.

BUILDING TYPES FLEXIBILITY

- a. Maximum number of floors/degree of independent support structure necessary.
- b. Ease of incorporating ancillary functions, (parking, commercial, laundry, etc.).

- c. Ease of incorporating mechanical, and service subsystems.
- d. Flexibility to offset facade.
- e. Flexibility to offset for terracing.
- f. Cantilever possibilities.
- g. Ability to rotate units on top 90°.

ADAPTABILITY TO VARIOUS SITE CONDITIONS

- a. Adaptability to different topographical conditions. (Units can vary in elevation.)
- b. Adaptability to sites having difficult dimensional constraints.
- c. Unit or component used below grade?
- d. Exterior cladding (for different climatic conditions).
- e. Dwelling Unit Density Range.
- f. Height/Width/Length Limitations (in quantum of module size).

INDICES FOR COMPARING SYSTEMS

INDICES FOR COMPARING SYSTEMS

Amount of total project time:
proportion on-site and off-site.

Weight/sq. ft. or sq. meter of dwelling
area.

Labor input/sq. ft. or sq. meter of
dwelling area (man-hours and costs).

Monetary cost/sq. ft. or sq. meter of
dwelling area (or cubic volume).

Breakdown of materials input per sq. ft. or
sq. meter (amounts and costs).

Percentages of total building cost alloca-
ted to:

- Erection
- Transportation
- Factory cost of components
- On-site labor costs
- On-site materials costs
- Foundation costs

Detailed breakdown of costs

Operating and maintenance expenses.

Technical performance characteristics

TABLES

1. Dimensions
2. Weight/Unit or Component
3. Type Wall, Thickness and U-Factor
4. Type Roof, Thickness and U-Factor
5. Erection or Joint Method
6. Foundation Type
7. Framework Required
8. Crane or Special Machinery Required
9. Size of Preparation or Erection Area
10. Reinforcement Types
11. On-site Labor
12. Integration with HVAC
13. Integration with Electrical
14. Integration with Water in Waste
15. Door on Window Openings
16. Prefinishing Options
17. Safety of Erection Process
18. Type of Interior Finish Possible
19. Type of Exterior Finish Possible
20. Range of Transport Economical
21. Labor Requirements

COSTS

A manufacturer must undertake elaborate and lengthy cost-estimates to determine what his product will cost. If the 'systems' building is comprised of several packages such as structure, mechanical, electrical, etc., the problem is compounded by the great variety of choices available. Each alternative situation must be reviewed in order to determine the most profitable combination of packages.

To the manufacturers' basic cost must be added numerous variable expenses such as transportation, erection, profit, overhead--all of which are increasing at different rates.

The developer must take into account financing costs, professional fees, cash flow, land costs, taxes, etc.

The consumer is interested in the monthly rent or mortgage payment, operating (fuel, electricity, water, etc.) costs, taxes, and maintenance.

Moreover, real costs of construction are never known, since the overhead and profit of the contractors included in the contract sum are generally not divulged.

Main features influencing construction costs of an apartment building are:

1. Foundation and site (location of project access, etc.)
2. Type of structural system
3. Architectural treatment
4. Mechanical systems
5. Electrical
6. Height of building/No. of floors
7. Floor area on each level (building dimensions)
8. Amount of special partitions, finishes, and detailing = quality of construction (special user requirements or extras)
9. Time
10. Degree of competitive bidding (Market conditions at the time of bids)
11. Builder familiarity with the system (Risk)
12. Prevailing labor rates

FHA MINIMUM PROPERTY STANDARDS

FOR MULTIFAMILY HOUSING, 1973 (CONDENSED)

ROOM AREAS

LIVING, DINING, BEDROOMS, OTHER HABITABLE ROOMS

Living Area

- a. Each dwelling unit shall contain space that is conducive to general family living and group activities such as entertaining, reading, writing, listening to music, watching television, relaxing and frequently children's play.
- b. Space shall be provided in the living area to accommodate the following furniture or its equivalent with comfortable use and circulation space:
 - 1 - couch, 3'-0" x 6'-10"
 - 2 - easy chairs, 2'-6" x 3'-0"
 - (1 - for efficiency apt.)
 - (3 - for 4 or more bedroom units)
 - 1 - desk, 1'-8" x 3'-6"
 - 1 - desk chair, 1'-6" x 1'-6"
 - 1 - television set, 1'-4" x 2'-8"
 - 1 - table, 1'-6" x 2'-6"

Dining Area

- a. Each dwelling unit shall contain space for dining. This area may be combined with the living room or kitchen, or it may be a separate room.
- b. Space for accommodating the following size table and chairs with proper circulation space in the dining area shall be provided for the intended number of occupants as shown:
 - (Efficiency or 1 bedroom) 2 persons, 2'-6" x 2'-6"
 - (2 bedrooms) 4 persons, 2'-6" x 3'-2"
 - (3 bedrooms) 6 persons, 2'-4" x 4'-0" or 4'-0" round
 - (4 or more bedrooms) 8 persons, 3'-4" x 6'-0" or 4'-0" x 4'-0"
 - Dining chairs, 1'-6" x 1'-6"

Bedrooms

- a. Each dwelling unit shall have space(s) allocated to sleeping, dressing and personal care.
- b. Each bedroom shall accommodate at least the following furniture or its equivalent with comfortable use and circulation space:
 - (1) Primary Bedroom: (required in each non-elderly living unit except efficiency)
 - 2 - twin beds, 3'-3" x 6'-10"
 - 1 - dresser, 1'-6" x 4'-4"
 - 1 - chair, 1'-6" x 1'-6"
 - 1 - crib, 2'-6" x 4'-6" (may be located in another room in addition to the required furnishings)
 - (2) Double Occupancy Bedroom
 - 1 - double bed, 4'-6" x 6'-10"
 - 1 - dresser, 1'-6" x 3'-6"
 - 1 - chair, 1'-6" x 1'-6"
 - (3) Single Occupancy Bedroom: (not permitted in public housing *except housing for the elderly*)
 - 1 - twin bed, 3'-3" x 6'-10"
 - 1 - dresser, 1'-6" x 3'-6"
 - 1 - chair, 1'-6" x 1'-6"
 - 1 - desk, 1'-8" x 3'-6" *for housing for the elderly*
- c. In housing for the elderly, beds shall be accessible from two sides and one end.
- d. In housing for the elderly, a convenience outlet for receiving a night light shall be provided between the bed location and the bathroom.

Other Habitable Room, (OHR)

An OHR may be provided for use as a den, family room, etc. Where provided, the room shall accommodate the required furniture for a single occupancy bedroom.

401-3.6 Optional Minimum Room Sizes Based on Sq. Ft. Area

Table 4-1.1 may be used in lieu of furnishability requirements in 401-3.1 through 401-3.5. When the table is used for any room, it shall be used throughout the project for all rooms of living units.

TABLE 4-1.1

MINIMUM ROOM SIZES

A. Minimum Room Sizes for Separate Rooms

Name of Space(1)	Minimum Area (Sq Ft) (7)					Least Dimension
	LU with 0-BR	LU with 1-BR	LU with 2-BR	LU with 3-BR	LU with 4-BR	
LR	NA	160	160	170	180	11'-0"
DR	NA	100	100	110	120	8'-4"
BR (primary) (2)	NA	120	120	120	120	9'-4"
BR (secondary)	NA	NA	80	80	80	8'-0"
Total area, BR's	NA	120	200	280	380	-----
OHR	NA	80	80	80	80	8'-0"

B. Minimum Room Sizes for Combined Spaces

Combined Space (1) (4)	Minimum Area (Sq Ft) (7)					Least Dimension (3)
	LU with 0-BR	LU with 1-BR	LU with 2-BR	LU with 3-BR	LU with 4-BR	
LR-DA	NA	210	210	230	250	
LR-DA-SL	250	NA	NA	NA	NA	
LR-DA-K (5)	NA	270	270	300	330	
LR-SL	210	NA	NA	NA	NA	
K-DA (6)	100	120	120	140	160	

Notes

(1) Abbreviations:

LU = Living Unit	K = Kitchen
LR = Living Room	NA = Not Applicable
DR = Dining Room	BR = Bedroom
DA = Dining Area	OHR = Other Habitable Room
0-BR = LU with no separate Bedroom	SL = Sleeping Area

(2) Primary Bedrooms shall have at least one uninterrupted wall space of at least 10 ft.

TABLE 4-1.4

GENERAL STORAGE REQUIREMENTS

	Cubic Feet of Storage	
	Column 1 (1)	Column 2 (2)
0 BR	100	140
1 BR	150	200
2 BR	200	275
3 BR	275	350
4 BR or more	350	425

Notes

- (1) This storage shall be located entirely within the living unit.
- (2) At least one half of this storage shall be located within the living unit.
- b. Each living unit having one or more bedrooms shall have at least one separate closet for general storage or utility purposes located in a conveniently accessible place within the unit. This closet shall be at least 6 sq ft in area and full room height. The remainder of the general storage may be located in bedroom and coat closets provided this space is in addition to the required closet space.
- c. Common storage shall be in a dry area with space divided into lockable compartments or closets for each living unit.
- d. Where exterior project maintenance is performed by tenants, provide at least 50 cu ft additional storage space per living unit, conveniently located to the outside.
- e. Where the project is designed for families with children, provide at least 50 cu ft of storage space per living unit conveniently located to the exterior for bicycles, prams, etc.

ELEVATORS

Service Required

Elevators shall be provided in buildings of:

- a. Five or more stories;
- b. Four stories where deemed necessary by the HUD field office to satisfy market considerations;
- c. *Three or more stories in housing for the elderly;*
- d. *Two story housing for the elderly where central dining facilities are located on a floor level other than the floor level of living units which do not have cooking and dining facilities.*

Service Elevator

At least one service elevator shall be provided in elevator-type buildings for the loading of furniture and equipment.

Install at least one elevator in each of the fire compartments required by 405-5.2. As an alternative where elevators are grouped together off a lobby, the lobby may be separated from each fire compartment by a one-hour fire-rated wall and a 3/4 hr fire door.

CLEAR HEIGHTS

TABLE 4-1.5

MINIMUM CLEAR CEILING HEIGHTS

Habitable Rooms	7'-6"
Halls within living unit, Baths	7'-0"
Luminous Ceilings	
Within living unit	7'-0"
Public Corridor	7'-4"
Sloping Ceilings	at least 7'-6" for 1/2 the room with no portion less than 5'-0"
Public Corridors	7'-8"
Public Rooms	8'-0"
Basements without Habitable Rooms	6'-8"

EXITS & CIRCULATION

Exit doors other than from individual living units shall swing in the direction of exit travel; exit doors giving access to public stairways shall not overlap the required effective width of the landing more than 6 in.

Screens shall be provided at exterior apartment doors and at all windows below the ninth floor except where not customary in the locality.

Door and window openings shall be planned to take advantage of adjacent exterior conditions and to avoid violation of interior privacy.

An access opening of 18 in. x 24 in. minimum shall be provided to each crawl space and an access opening of 14 in. x 22 in. minimum shall be provided to each attic space. See Table 6-1.1.

When the attic or crawl space contains mechanical equipment, the access opening and any accompanying areaway shall be of sufficient size and shape to permit replacement of the equipment.

Attic and crawl space access openings shall not be located within living units.

HALLS AND CORRIDORS

Halls and corridors shall provide convenient, safe, and unobstructed circulation within living units, and between living units and other spaces to various means of exit.

Minimum clear widths of halls and corridors shall be:

a. Public halls:

<u>Length</u>	<u>Width</u>
Less than 10 ft	3'-6"
10 ft to 30 ft	4'-0"
30 ft to 100 ft	4'-6"
More than 100 ft	5'-0"
<i>Housing for elderly</i>	5'-0"

b. Exterior access corridors: 5 ft

c. Halls within living units: 3 ft

d. Halls within living units for wheelchair access: 3 ft - 4 in.

- e. The width of corridors at elevators shall be greater than the width of the corridor at other locations, except where the elevator is serving six living units or less per floor. The increase in width shall be at least 20 percent for corridors or hallways less than 5 ft wide, and at least 12 percent for corridors from 5 ft to 7 ft wide.

Projections, except handrails, and obstructions such as columns and door swings shall not reduce the required width. Screen and storm doors may swing into exterior access corridors but drinking fountains, exterior awnings or casement window swings, etc. shall not reduce the required width.

All exits shall provide a continuous and unobstructed means of travel from any point in a building to a public way.

Maximum Lengths

- a. In corridors affording access to a stairway or horizontal exit in two directions, the distance between a living unit entrance and a stairway or horizontal exit shall not exceed 100 ft measuring from the center lines of the doorways. This distance may be increased to 150 ft where building is protected by automatic sprinklers.
- b. In dead-end corridors affording access in only one direction to a required exit, the distance between a living unit entrance and the exit shall not exceed 35 ft measuring from the center lines of the doorways.
- c. The distance of travel within a living unit between the door of the most remote room and a doorway to an exit corridor shall not exceed 50 ft.
- d. The distance of travel to an exit stairway or exterior door from any point within a boiler room or other area of high fire hazard shall not exceed 50 ft.


CIRCULATION

Each bedroom shall have access to a bathroom without an intervening bedroom, kitchen, or principal living or dining area. Bedrooms shall not afford the only access to a required bathroom, except in one bedroom units. Neither a bedroom nor a bathroom shall afford the only access to a habitable room.

FLAME SPREAD RATINGS

TABLE 4-5.4

FLAME SPREAD RATING AND SMOKE GENERATED LIMITATIONS OF INTERIOR FINISHES
(1) (4) (5)

Location Within Building	Surface Flame Spread Rating- Maximum Range		Maximum Optical Smoke Density	
	Walls & Ceil.	Floors	Walls	Ceil. Floors
Enclosed Stairways and Other Vertical Openings	0-25	0-75 [4]	Reserved- pending evaluation of test procedures.	
Corridors or Hallways and Other Exits	0-75	0-200 [8]		
Within Living Unit except for Kitchen (3)	0-200			
Kitchen Space within Living Unit (2)	0-75			
Public Rooms and Entrance Spaces	0-75	0-200 [8]		
Lobbies and Corridors between Exit Stairway and Exterior	0-25	0-75 [4]		
Service Rooms, enclosing Heat Producing or other Mechanical Equipment, and all other Fire Hazardous Areas	0-25			

Notes

Abbreviations: Ceil. = Ceiling
[] = Index number for UL Standard No. 992

- Single or double doors and windows having a total area of not greater than 34 sq ft, trim around openings, baseboards, moldings, chair rails, bathroom wainscot and plumbing fixture may be excluded in the calculation of flame spread limitations for rooms or other spaces.
- The flame spread rating of kitchen cabinets and counter tops shall not exceed 200.
- Flame spread rating of walls and ceiling in housing for the elderly = 0-75.
- Draperies when provided shall be flameproof in accordance with NFPA Standard No. 701 "Flameproof Textiles."
- Where automatic sprinkler protection is provided, the flame spread ratings may be increased in the following amounts; 0-25 to 0-75 and 0-75 to 0-200.

MISC.

FIRE EXTINGUISHING SYSTEM

- For all buildings four stories or more in height, an automatic sprinkler protection system shall be provided in all corridors, public spaces, service areas and utility areas.
- Sprinkler systems shall be equipped with an automatic alarm initiation device that will activate the general alarm system for the building.

Installation of fire alarm and extinguishing systems shall be in accordance with NFPA No. 72A for fire alarm systems and NFPA No. 13 for sprinkler systems. Spacing of sprinkler heads in corridors shall be positioned 15 feet on maximum centers.

STANDPIPES

All buildings 5 stories or 55 ft or greater in height shall be equipped with wet standpipes of number, size and construction in accordance with NFPA No. 14 "Standpipe and Hose Systems" for Class I services.

BUILDING DISTANCE SEPARATION

The minimum distance of a building from a lot-line is determined by 304-2 for planning purposes. See also Table 4-5.1 for fire protection requirements. The following additional provisions relate to the distance of a building to a lot-line or another building:

Where there are openings in an exterior wall less than 10 ft from a parallel wall having an exterior finish with a flame spread rating greater than 25, provide protected openings having a 3/4 hr fire endurance in accordance with ASTM E 163.

Unprotected openings shall not be more than 20 percent of the total wall area when distance separation is 10 to 20 ft and 30 percent when distance separation is 20 to 30 ft.

PENTHOUSES

..... a penthouse not over 15 ft above the roof and set back from the edge of the roof more than 8 ft is not required to have a designated fire resistance rating.

LIGHT & VENTILATION

TABLE 4-3.1

MINIMUM REQUIREMENTS FOR ARTIFICIAL AND NATURAL LIGHT
NATURAL AND MECHANICAL VENTILATION

Location	Artificial Light Footcandles (11)	Nat. Light Glazed Area As % of Floor Area	Natural Ventilation, Opening As % of Hor. Projection	Mechanical Ventilation Air Changes Per Hour (1)
<u>Public Areas</u>				
lobby (general)	20	--	5	or 4 supply(10)
dining	30	10	--	6 supply
corridors	20	--	--(2)	4 supply(10)
stairs	20	--	5	or 4 supply(10)
general storage	10	--	2	or 2
laundries	30	--	5	or 6 exhaust
garages (general)	10	--	see 615	
recreational areas	(3)			
arts and crafts	70	15	5	or 6 supply
game rooms	20-30	--	5	or 6 supply
<u>Exterior Areas</u>				
self-parking areas	1	--	--	--
walk-ways	1	--	--	--
building entrances	4	--	--	--
steps	4	--	--	--
<u>Living Units</u>				
living rooms	--	10	5	10(4)
dining rooms	--	10	5	10(4)
bedrooms	--	10	5	10(4)
other habitable rooms	--	10	5	10(4)
kitchens	--	--	5	or 8 exhaust(8)
baths	--	--	5	or 5 exhaust (9)
laundry	--	--	--	(5)
<u>Structural Spaces</u>				
attics & spaces	--	--	1/150(6)	--
basementless spaces	--	--	1/800(7)	--

STC

TABLE 4-4.1

SOUND TRANSMISSION LIMITATIONS

LOCATION OF PARTITION	STC	
Living unit to living unit, corridor (1) or public space (average noise) (2)	45	
Living unit to public space and service areas (high noise) (3) (5)	50	
LOCATION OF FLOOR-CEILING	ETC	IIC
Floor-ceiling separating living units from other living units, public space (4) or service areas (2)	45	45
Floor-ceiling separating living units from public space and service areas (high noise) (3) including corridor floors over living units.	50	50

Notes

- (1) These values assume floors in corridors are carpeted; otherwise increase STC by 5.
- (2) Public space of average noise includes lobbies, storage rooms, stairways, etc.
- (3) Areas of high noise include boiler rooms, mechanical equipment rooms, elevator shafts, laundries, incinerator shafts, garages and most commercial uses.
- (4) Does not apply to floor above storage rooms where noise from living units would not be objectionable.
- (5) Increase STC by 5 when over or under mechanical equipment which operates at high noise levels.

FIRE PROTECTION

INTERIOR FIRE PROTECTION

Firewalls, and Lot-Line Walls

- a. Firewalls, and lot-line walls shall form a continuous fire and smoke barrier between fire divisions from foundation to the roof and be so constructed as to assure structural stability in the event the construction on one side is removed or destroyed by fire.
- b. For firewalls, and lot-line walls where the roof framing, sheathing and covering are combustible, the fire division wall shall extend at least 18 in. above the top of the roof.
- c. Fire and lot-line walls may be carried up to the underside of the roof sheathing and sealed tightly in the following conditions:
 - (1) Where construction is Type 1 or Type 2.
 - (2) Where the roof construction provides one hour protection against sheathing burnthrough with a Class A brand (tested in accordance with Method C Burning Brand Test ASTM E108) for a width of 6 ft on each side of the wall and roof covering material throughout is at least Class C classification (ASTM E108).
- d. Metal conduit-protected wiring and outlets may be installed in fire rated partitions, lot-line walls, and firewalls except that outlets shall not be installed back-to-back. Heating ducts and plumbing may be placed in firewalls only where the wall construction provides a minimum of 2 hr fire resistance rating on each side of the ducts or plumbing. Recessed cabinets shall not be placed in firewalls.

Firestopping

- a. Firestopping shall be provided in all walls and partitions, floors, stairs, attic or cornice construction, around chimneys, pipe and duct openings, to cut off all concealed draft openings, horizontal and vertical, so as to form an effectual fire and smoke barrier between stories and between the upper story and the roof.

TABLE 4-5.1

FIRE PROTECTION REQUIREMENTS
MINIMUM FIRE RESISTANCE RATINGS IN HOURS BY TYPES OF CONSTRUCTION (1)

ELEMENTS OF CONSTRUCTION	TYPE 1	TYPE 2		TYPE 3		TYPE 4
		2a	2b	3a(2)	3b(6)	
EXTERIOR WALLS						
Bearing						
Under 30 ft separation	2	2	1	2	2	1
30 ft and over separation	2	2	3/4	2	1	3/4
Non-bearing						
Under 10 ft separation	2	1	1	2	2	1
10 ft to 30 ft separation	1	1	3/4	1	1	3/4
Over 30 ft separation	0	0	0	0	0	0
INTERIOR WALLS AND PARTITIONS						
Fire, and lot-line walls	2	2	2	2	2	2
Bearing	2	1	1	2	1	1
Non-bearing	NC(5)	NC(5)	NC(5)	C	C	C
Exit enclosure of stairways, elevator shafts, etc. (3)	2	2	1	2	1	1
Partitions separating living units and enclosing public corridors	1	1	1	1	1	1
COLUMNS, BEAMS, GIRDERS, TRUSSES	2	2	1	2	1	1
FLOOR CONSTRUCTION (10)	2	1	1	1	1	1
ROOF CONSTRUCTION (4)	1	1	3/4	1	1	3/4
WALLS, FLOORS AND CEILINGS						
1. Of lobbies and corridors between exit stairways and exterior	2	2	1	2	1	1
2. Separating commercial from residential	2	2	2	2NC	2NC	2
3. Enclosing service spaces (9)	2	2	2	2	2	2
4. Enclosing tenant general storage area	1	1	1	1	1	1
5. Separating garage from residential						
For 1 to 4 cars	1	1	1	1	1	1
For more than 4 cars	2	2	2	2	2	2
PUBLIC STAIRWAYS	NC	NC	NC	NC	C(7)	C(7)
EXTERIOR STAIRWAYS AND CORRIDORS	NC	NC	NC	NC	NC(8)	NC(8)
SHAFT ENCLOSURES	2	2	1	1	1	1
CONSTRUCTION ENCLOSING BOILER, HEATER OR INCINERATOR ROOMS, FUEL STORAGE AND TRASH CHUTES (11)						
	2	2	2	2	2	2

Notes for Table 4-5.1

(1) Abbreviations:

O designates that no specific fire resistance rating is required.
L.U. = Living Unit
NC designates noncombustible construction, but no specific fire resistance rating is required.
C designates that the structural members of the construction may be of combustible materials, but no specific fire resistance rating is required.

- (2) In type 3a construction the corridor walls, floors and ceilings, partitions enclosing vertical openings, stairways, columns and beams shall be 2-hr. noncombustible for structures of 3 or more stories, and 1-hr. noncombustible for one or 2 stories.
- (3) In buildings of types 1, 2a and 3a construction, not more than 3 stories in height, and having not more than 12 living units within a fire division, exit enclosures may have a fire resistive rating of one hour.
- (4) Roof construction with ventilated attic need only have ceiling assemblies with a finish rating of at least 20 minutes.

MAXIMUM HEIGHT AND AREA LIMITATIONS

Floor area, per floor, in sq ft, according to type of construction
(1) (2) (3)

Maximum Height		Type 1	Type 2		Type 3		Type 4
Stories	Feet		2a	2b	3a	3b	
8 or more	U	U	NP	NP	NP	NP	NP
7	80	U	12,000	NP	NP	NP	NP
6	70	U	15,000	NP	7,500	NP	NP
5	60	U	20,000	NP	10,000	NP	NP
4	50	U	24,000	6,000	12,000	9,000	NP
3	40	U	27,000	9,000	15,000	12,000	9,000
2	30	U	30,000	12,000	18,000	15,000	12,000
1	15	U	33,000	15,000	21,000	18,000	15,000

Notes

- (1) Abbreviations: U = Unlimited: NP = Not Permitted

Where a building is equipped throughout with an approved automatic sprinkler system, the maximum allowable areas given Table 4-5.2 may be increased by 50 percent.

EXITS

General

- a. Exit systems shall be of the number, size, arrangement and capacity (number of persons) to permit prompt escape of occupants in the event of fire or other hazardous conditions.
- b. All means of egress shall provide a continuous and unobstructed path of travel from any point in the building to a public way.
- c. For additional egress requirements, see 402.

Number of Exits

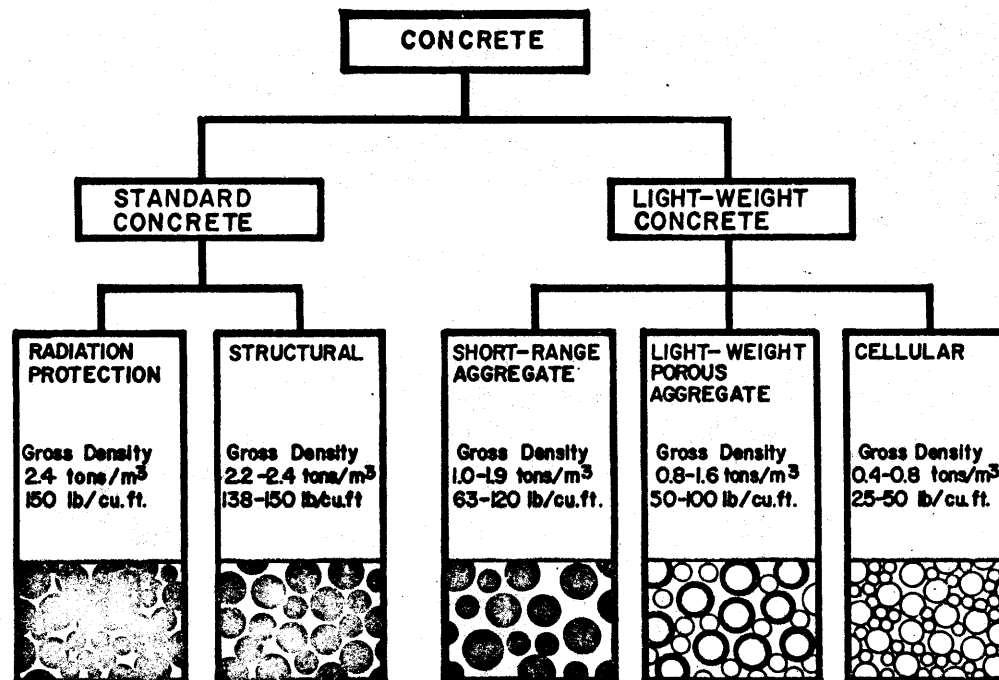
Every living unit shall have access to at least 2 separate exits which are remote from each other and are reached by travel in different directions, except that a common path of travel is permitted under certain conditions see 402-4.3 and 405-6.3.

Conditions Where a Single Exit is Acceptable (Except for item (a) below, a single exit is not acceptable in housing for the elderly)

- a. A living unit having direct exit to a street or yard at ground level, or by way of an outside stairway serving the living unit only.
- b. A one story building containing a maximum of 8 living units.
- c. A 2 story building containing a maximum of 8 living units and not more than 4 units per floor with one hr fire resistive enclosed stairway immediately accessible to all living units.
- d. A 3 or 4 story building having not more than 4 living units per floor with a smokeproof tower, or 2 hr fire resistive enclosed stairway immediately accessible to all living units.

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1 Metric Ton = 1,000 kilograms = 2,205 lb.
 1 ton/m³ = 62.44 lb./cu. ft.

CONCRETE: Some Characteristics

Concrete is defined as:

"A mixture composed of a paste binding together an inert filler, or aggregate. The paste is formed by the chemical reaction between cement and water.

The paste or cementing medium is the fundamental basis of strength development of concrete. The inherent strength of the paste is a function of the ratio of its two components expressed in gallons of water per sack of cement.

In a concrete mixture, the maximum amount of aggregate should be used to produce an economical mix with low shrinkage. The amount of aggregate used depends on its effect on the workability or consistency of a mix. The limiting amount, then, is the maximum amount that can be used and still attain full compaction of the concrete. Consistency is determined by 'slump' tests, which measure the number of inches a mass of concrete will settle after the slump cone has been removed from the concrete." [1]

In order to reduce the weight of a concrete box-unit, thinner but stronger walls could be used, or lighter-weight concrete could be used.

According to Diamant, Russian concrete box-units have a thickness of only 1 5/8" between ribs on the side walls and ceiling, using fine grain concrete. [2]

ACI codes require structural members to be at least 4" thick, [3] and for panels 8 cm. or 3.2 in. is required to prevent buckling. [4]

There is, of course, a practical limit to the weight and thickness of concrete box-units usually determined by transport and handling stresses.

While for fireproofing, minimum steel cover is 3/4" [5], ease in filling molds and removal from molds limits non-bearing panels to 6 cm. or 2.4 inches. [6] The type of mold or process will determine the lowest limit for each application.

The minimum panel to accommodate a post-tensioning sleeve is 5" [7]. If electrical conduit and outlets, or if heating cables are imbedded in the concrete, allowance must be made. It is necessary to use a very high slump concrete so that it will communicate around these required inserts. This necessi-

tates a mix which has more water than would be required for the concrete process itself. Therefore, in order to maintain the proper water-cement ratio, cement must be added and this adds cost.[8]

The Zachry system used a 5" wall of lightweight expanded shale aggregate and silica sand, an air- entraining agent, and a workability agent. The net weight of this wall was 95 pounds per cubic foot. "The results from this wall have been very good insofar as heat transmission is concerned. The economics insofar as materials are concerned is good, but other problems of labor and temperature cracking still need work before the wall can be considered an unqualified success." [9]

"Up to a point strength can be maintained while reducing the weight of a concrete. However, weight reductions achieved at a constant strength are not sufficient to contribute significantly to either the handling problem or the heat transmission problem. In order to make an important contribution to the weight problem, air entrainment, foam, insulating aggregates or some esoteric structural shape is required. When significant reductions in weight are achieved by lowering the density of concrete, the strength is reduced and the durability of the surface of the walls is decreased.

In the case of horizontal concrete sections such as the roof, the much lower modulus of elasticity of the low density concretes

practically prohibits their use, unless some very good moments of inertia can be achieved by the development of deep cross beams, waffle-type slab arrangements, or the addition of reinforcing steel.[10]

LIGHTWEIGHT CONCRETE--CELLULAR CONCRETE

Lighter-weight concrete is being developed. This is accomplished by:

1. Using lighter aggregates.
2. Using additives to entrain gas bubbles to produce a cellular concrete.

Cellular concrete is usually non-structural, with densities from 25 to 50 pounds per cubic foot (0.4-0.8 metric tons per cubic meter).

One of the leading producers of cellular concrete in Europe is the HEBEL Gasbetonwerk in Emmering, Germany. Their product is available in many forms of panels and blocks for all purposes, but most interesting for use in box-unit construction would be large panels. [11]

Bearing panels are available in standard sizes: 600 cm x 60 cm x 7.5-25 cm.

19'-4" x 2'-0" x 3" to 10"

Non-bearing panels are available in standard sizes: 600 cm x 150 cm x 12.5-25 cm.

19'-4" x 4'-11" x 5" to 10"

It is possible that larger size panels could be produced in the future, given sufficient

demand. (A panel for box-unit walls should be obtained in one piece, about 9 ft. x 30 ft. or 2.74 m x 9.14 m

LIGHTWEIGHT CELLULAR CONCRETE

Another product is SIPOREX, a chemical mixture with lime and cement that rises in its mold, much the same as a cake would rise, forming a cellular structure weighing 31 pounds per cubic foot. It can be shaped, sawed, drilled, sanded or routed similar to wood, permitting close tolerances and good construction joints. [12]

CONCRETE WITH LIGHTWEIGHT AGGREGATES

A prediction is for pyroprocessed shales and clays to increase in use where the supply of good, natural aggregates dwindles. From these materials will come concrete with a specific gravity of 0.8 and strength over 3,500 psi. [13]

Additives may be fly ash, blast-furnace slag, manufactured aggregates such as brick, iron concentrates, activated carbon, alumina, and other minerals. [14]

Mapleton Development, Inc. has developed 'SCR veri-lite', a bubble-like expanded clay product with a density of 28 pcf with excellent insulating properties. When mixed with appropriate cement ratios, it results in a concrete 4" panel with a U-factor of 0.30

Btu/hr./sq. ft./°F. At a density of 65-67 pcf, a compressive strength of 5,000 psi is achievable. [15] This concrete is being used in a panel faced with a 1-3/4" split brick unit for a total thickness of 4", by the Royal Development Division of Metropolitan Industries in Canton, Ohio. A 4' x 9' brick faced panel weighs 1,200 pounds, or 100 pcf.

CONCRETE WITH PLASTIC AGGREGATES

Rudolf Doernach, a German architect and former assistant to R. Buckminster Fuller demonstrated a "space unit" at Constructa '70, the big German construction show held in Hanover. Doernach holds the patent on his space-unit system, and the specific additives and their mixing ratios as well as the mixing machinery are protected by BASF held patents.

The material used consists of a mixture of small STYROPOR plastic balls (0.978-0.1575 inc. in diameter) with Portland Cement, epoxy resins for adhesion and small doses of some 20 polyvinyl additives. The plastic balls, or pellets are hollow, providing insulation, low weight, and easy workability.

The plastic-to-concrete ratio is about 22 to 33 lb. of pellets to a cubic foot of concrete. By volume, the STYROPOR accounts for about 90% of the total.

Doernach varies the additive proportions for specific material characteristics, such as fire rating, thermal and sound insulation,

stability, steam permeability, etc.

Each 11-1/2 ft. x 26-1/2 ft. x 9 ft. space consists of a shell of 3.15 in.-thick plastic-concrete panels covered on exterior surfaces with another 10.16 in. of STYROPOR for added thermal insulation.

Up to now, the prototype units have been bolted together from panels molded in horizontal forms. Panels can be removed from the forms in one day, but they need to harden for another 8 to 14 days before they can be assembled. Like conventional concrete, they achieve maximum strength in 28 days.

Work is also underway on a similar system, but with water instead of air inside pellets.

Doernach so far has spent more than \$4 million on this project--funds from private industry, government sources, and his own pocket. Plans, not yet disclosed, are in the works for a cooperative arrangement between Doernach's group of 10 members (architects, city planners, material breeders, construction men, and administrators) and a similar group in Tokyo.[16]

Additives for reinforcing metal, mineral, glass, or plastic fibers are being experimentally used to reinforce concrete.

An experimental house being demonstrated in January 1975 by the National Association of Home Builders (NAHB) in Dallas, Texas features a 3,300 sq. ft. glass-fiber reinforced concrete floor slab. According to Ernest L. Buckley, director of the Construction Research Center in Dallas (CRC), the 1" long glass fibers in a mixture of 1.5-2% by volume in the 4-in. slab provide a flexural strength equal to steel fibers, but unlike steel, the alkali-resistant glass fibers do not ball up and are safe to handle. "The glass fiber reinforced concrete is seven times more resistant to fracture than conventionally reinforced concrete using No. 3 steel bars on 16-in. centers, Buckley claims. Concrete reinforced with glass fiber is not yet commercially available, and the Dallas project may be its first residential test, he says." [17]

Reinforcement will also become more mechanized with rebarring and welded wire handled by machines. On contractor replaces rebars with expanded wire mesh in flat panels when strength in only one direction is required.[18]

Precasting and prestressing methods will be improved for lighter sections, although the campher resulting from pre-stressing requires a topping layer.

STRUCTURAL CONNECTIONS

Structural connections and detailing become increasingly important as the size of the structural elements being used increases.

The advantages of on-site connections which strengthen the structure through continuity of shell reinforcing may be over-ridden by savings in time and labor when the building is designed for simple connections (non-moment transferring joints) with reliance on bulk, shear walls, cores, ring-beams, or cables for rigidity.

Some predict that concrete precast buildings will depend to a large extent on glued joints for resistance to thermal and seismic forces.[19] Development of special concrete adhesives parallels the development of glues for wood construction.

CONCRETE MIX CAUTION

To enable concrete to cure faster, use of high-alumina cement (HAC) had been popular in Great Britain. (HAC is not used in the United States or in European structures.)

Unfortunately, this cement has now been found to be unsafe. As many as 50,000 buildings in Great Britain are a potential hazard because they were constructed with HAC, according to the country's Department of the Environment.[20] An ensuing investigation by Britain's Building Research Establishment found that in high temperatures and humidity, a chemical process

known as conversion alters HAC's crystalline structure, causing a loss of strength. The investigation was ordered after HAC was found to be a contributing cause of the collapse of three school roofs last year.

SHRINKAGE

A monolithically cast concrete house will invariably develop cracks from shrinkage of the concrete. A concrete house assembled from panels will not have such a serious problem. Cracks also develop around window and door openings.

Since cracks in the walls are not acceptable by the occupant, further development to solve the problem must be made or the walls must be covered with a vinyl wall covering or nylon base paints which will stretch and bridge cracks up to 1/16".[21]

"Practice shows that many of the box-units get cracks which damage finishing, deteriorate sound insulation, and reduce the load-bearing capacity of the box-units. Therefore measures aimed to prevent cracking of the box-units deserve special attention."

The following means for reducing cracking seem possible.

1. The application of more harsh concrete mixtures and 'soft' regimes of curing

(heat treatment).

2. The use of special cements including expanding and fast-setting ones (eliminating the heat treatment).
3. Prestressing of reinforcement. [22]

Some of the above-mentioned methods are being developed in this country.

FINISHING OPERATIONS

The sequence of finishing operations, time, and labor consumption depend upon the future function of a box-unit. The finishing time for a box-unit comprising a kitchen, a bath-room and w.c. is twice as long as that for a box-unit comprising flights of stairs or rooms of a dwelling. [23]

The Russians employ the following sequence of operations at the finishing conveyor:

1. Assembly of tubes for hot and cold water supply, sewage, gas, central heating.
2. Fixing doors and window frames.
3. Finishing floors, installing built-in cupboards, ventilation-grills, finishing seams between the walls and details.
4. Assembly of electric wiring, finishing w.c. floors with ceramic tile and the preliminary hot-air drying of internal surfaces of the box-unit.

5. White washing of ceiling, papering of walls, oil-painting and the drying of wall-panels, windows, doors, tubes and floors.
6. Installation of the sanitary and service equipment, gas-stoves and filaments, final finishing with paints and hot-air drying of wall-panels and floors.
7. Hot air drying of internal surfaces of a box-unit.
8. Technical control and storage. [24]

FINISHING PROBLEMS

New products must be developed to increase the efficiency of factory finishing operations.

Finishing compounds should be weather-proof, sufficiently adhesivable with regard to concrete surfaces which are from 10 to 18% humid, and be air-dryable at 15-18 C = F.

The use of oil and other long-drying paints makes it necessary to air-dry the products as long as for 50-60% of the whole manufacturing period. [25]

MOLDING BOX-UNITS

Molding the box-units within a wide-range of sizes may be accomplished by either

1. having reserve capacity or
2. using flexible molding equipment.

Flexible equipment developed in Russia "separates the forms which determine the dimensions and configuration of the box-units from the service mechanisms. It allows to construct rather simple universal machinery and unified forms." [26] A change of a single mold taken 407 man-hours and has to be carried out at a specialized post of the technological line; an additional form should be provided to keep up the productive capacity of the line." [27]

"In the forming systems required for monolithic modules, flexibility of design is minimum if it exists at all. This is because of the impracticability of building a large number of molds in order to achieve flexibility, or because of the expense of manufacture and high labor costs relative to the operation of a uniform type that can produce many different plans." [28]

"If a manufacturer decides to produce monolithic modules in concrete, he must be content with three or four different floor plans with perhaps four variations of the front elevation of ends. These front facades can be varied by changing the front trim of the house." [29]

MOLDING BOX-UNITS

The single most difficult problem encountered in the mass production of modular concrete homes is the development of the forming system for casting.

Zachry's experience showed that only the exterior shell should be cast; interior parti-

tions being more economically constructed of drywall later. [30]

Another aspect of the forming system that causes problems is the fact that all materials used in forming concrete are elastic, and under load they are going to deform. No matter how strong the forms are made, some deformation will take place. This is if the forms must be vibrated in order for the concrete to fill all the voids. Built-in tolerances must be designed to the form or the completed modules will not fit together properly.

In the pouring of the module some external vibration will be required in order to get even extremely high slump concretes to communicate properly. This vibration will be deleterious to the form itself even if it is of steel construction. Strengthening the form is not always the answer to this damage since the stronger form will require more vibration energy to get the same effect. A balance must be reached in the design to minimize its deformation under load and allow a moderate amount of vibration without requiring frequent form repair. Even with this balance, assuming it can be achieved, forms will have to be repaired from time to time. [31]

AUTOMATION

In designing the forms, consideration should be given to making their operation as auto-

matic as is economically feasible. Based on estimates of converting Zachry's forms to fully automatic, the additional cost would probably be about one-third the original cost of the forms. This is not excessive since the steel form's original high cost means that a large number of houses must be produced by their use in order to amortize them. The additional cost of automation then would probably be paid for by labor savings to be achieved by the automation in this large number of houses.

Whether the forms are completely automated or not, serious consideration should be given to making all strippable parts of the form self-aligning and self-locking, since in a form that is this complicated, the labor required to align the various parts and lock them in place can get to be a sizable percentage of the total labor required in casting.

The type of concrete used will depend on whether the box-unit is designed to be only self-supporting or designed to transmit loads from other units.

If the box-unit is only self-supporting, it must be designed to take loads of transport and handling, as well as gravity loads. Each box-unit can be conceived as form-work; after the boxes are placed, grout or concrete can be poured between the modules to form rigid continuous supports. Obviously,

this approach works best when box-units contain the entire dwelling unit within the shell. The size of the building should be such that time for concreting is allowed after modules are placed, so the concrete can harden overnight before the next layer of work commences.

A proposal by F. D. Rich, Jr. for the "HAB-System" modules shows boxes as beams, spanning the width of a building. [32] Supporting columns are located in rows, front and back, so standard boxes can be utilized in high rise construction of various heights by appropriate column sizes. (see Example 2, page 142) For purposes of reducing the weight of the box-unit, ribbed floors, walls, and ceiling are used. The wall sections are only one inch, the ceiling 1-3/4", and the floor about 2". [33]

An interesting approach to try would be to construct box-units of large panels of lightweight cellular concrete such as "Siporex" or "Hebel Gasbeton." The box-units would only be strong enough to support their own weight and for stresses during transport and handling. To construct a building, concrete would be poured between the walls, forming a monolithic structure.

An alternative method of producing concrete box-units would be to use the Conspray technique described on page 90. Using a previously precast floor, an interior steel form would be lined with a interior finish

(perhaps wood paneling) bonded to an insulating foam-like material (such as styrofoam). The attachments for the reinforcing "cage" could be stuck into the foam much as pins in a pin cushion and would be permanently "placed" after the unit was given a spray coat of 3" of concrete.

WEIGHT OF THE UNIT

The weight of the unit determines the capacities required for equipment used in moving the units about the precasting facility and also through the final assembly plant.

The crane capacity required for erecting the units as the job site is dictated by the weight of the module as well as by the building height.

FIRE LESS CRITICAL IN CONCRETE BOX-UNITS

The tunnel-affect between box-units is more severe in steel and wood units. Details of firestopping become critical.[34]

SPECIAL PROBLEMS

Technical Background. The average contractor or developer prefers to continue with methods familiar to him. "The risk was too great to go with a system where we totally

depend on other people's know-how," said Paul Koch who turned to conventional construction only after he was unable to get the necessary concrete engineering assistance.[35]

James Shilstone of General Portland, Inc. in a paper for the American Concrete Institute Conference held in Dallas, Texas in September, 1973 states:

"One reason is that most builders consider concrete an ugly duckling suitable for prisons or sewage project plants, but unsuitable for residential buildings. Cool and Grey are two words used to describe a grim rainy day and these are usually associated with the look of concrete, an association that has led one Colorado concrete builder wary of consumer acceptance to remark, 'We are not going to advertise the fact that we are making concrete houses.'"[36]

There is a need for industry-wide standards for dimension, connection, and material which must be evolved and accepted locally.

Methods of inspecting and certifying work transported across local and state boundaries must be developed. New equipment for making, transporting and placing precast components must be found, and a new labor category--the concrete erector--must develop.

MANUFACTURE

The manufacture and design of box modules are closely related. Early consultation with contractors and concrete firms is essential; in fact, the module producer would do well to acquire or merge with existing concrete manufacturers with established equipment and experience.

The following are considerations in the choice of design:

1. Units which require little time to manufacture because of simple shape and cross-section are often cheaper to mass-produce than cleverly contrived weight saving sections.
2. The structure should be composed of a small number of different types of structural components in order to minimize the number of different molds needed; to speed up the manufacture of equal units and the lower costs.
3. The units should be so designed that variants of basic types can be produced in the same mold.
4. Units should be designed for mechanized manufacture. [37]

My project envisions the use of steel molds which have the qualities of volu-

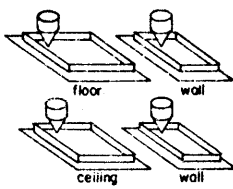
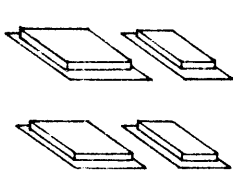
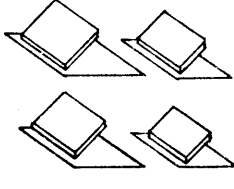
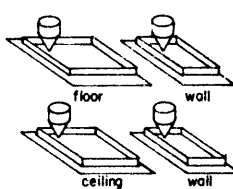
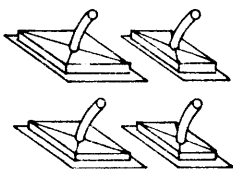
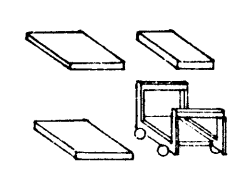
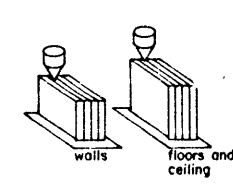
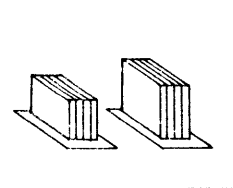
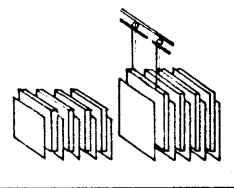
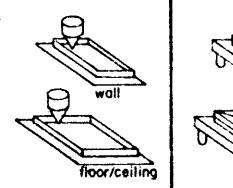
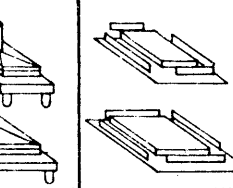
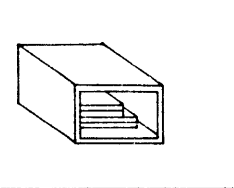
metric stability to produce dimensionally accurate units, are re-useable, have little adhesion, are easy to clean, are suitable for changes in mold dimensions, and can be vibrated.

Although battery molds could be used, casting on horizontal beds or slip-forming would be less expensive alternatives, especially when only one side of the wall or floor need be finished to a smooth surface.

In addition, fittings for electrical equipment, doors, connections, and placement of reinforcement is most economically achieved in flat molds and filling of concrete around openings is more compact. It will be necessary to use artificial hardening (curing) to enable demolding at an early age (e.g., tilting molds). Flat panels fill all the requirements of easy manufacture. Moreover, equipment to produce flat panels is readily available; existing plant and equipment can be used when a change-over to production of modules is introduced. Flat panels can be surfaced to resemble wood or brick or any other treatment simply by using an appropriate form liner; color additives, or ceramic tile or plastic coatings are easily applied, and sandwich panels are easily integrated with the system.

With reinforced (as distinct from prestressed) concrete, it is generally sufficient to

Some Methods of Producing Panels

				
MINIMUM INVESTMENT	POUR & LEVEL	CURE	TILT & REMOVE	
				
ACCELERATED CURING	POUR & LEVEL VIBRATE	CURE WITH HEAT (Hot air, infrared red, heated mold, etc.)	VACUUM LIFT TRANSPORTER	
				
BATTERY MOLDS	POUR & VIBRATE	CURE IN HEATED MOLD	OVERHEAD CRANE LIFT	
				
GO-CON PRESS	POUR & LEVEL	HYDRAULIC PRESS LIFTS MOLD TO PLATEN	SIDES RETRACT	CURING OUTSIDE MOLD (Extra handling)

SOURCE: ADAPTED FROM GO-CON CHART "COMPARISON OF PRECASTING TECHNIQUES"

attain between 25-60% of the final strength to enable them to be demolded and removed from the casting bed. With artificial treatments to accelerate hardening of the concrete, the required strength for demolding can be attained in as little as 2 to 4 hours depending on the type of cement and process used. Tilting tables or suction-lifters are used to facilitate removal from the forms. [38]

The reader wishing more detailed information concerning casting of concrete box-units should refer to

MANUAL OF PRECAST CONCRETE CONSTRUCTION
by T. Koncz, Volumes I, II, and III

CONTEMPORARY CONCRETE STRUCTURES
by August Komendant (pp. 524+)

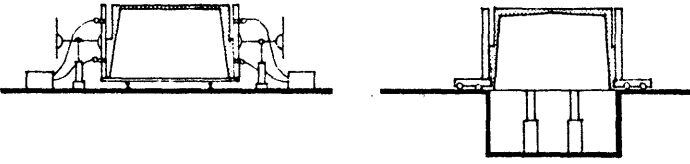
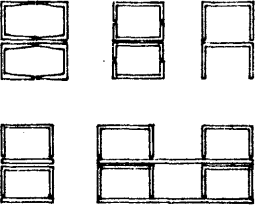
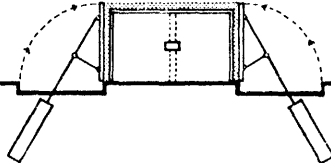
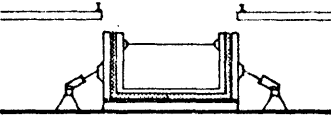
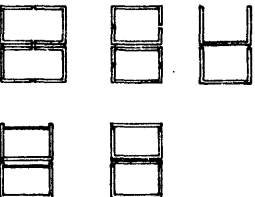
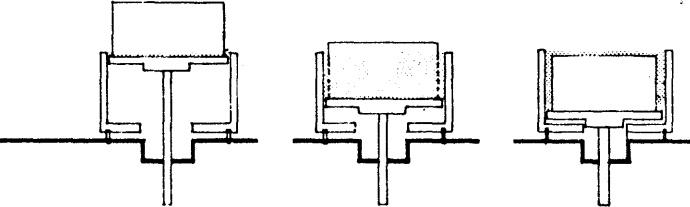
INTERNATIONAL SYMPOSIUM ON BOX-
UNIT CONSTRUCTION, 1973
CIB Proceedings #26
Balatonfured, Hungary

In addition, a brief survey of American firms is given on pages 94-99 of this paper. One firm, Allied General, Inc., has developed a new technique of injection molding with a rich cement mix of concrete.

The chart on the opposite page shows different types of molds; with the exception of the Hinged Mold described by A. Komendant, the examples are from Russia as described in the CIB Proceedings #26 just mentioned.

These machines seem cumbersome and expensive when compared with the spray-technique which follows.

Some Methods of Molding Units

CASSETTE MOLDS		
HINGED MOLD		
U OR CUP MOLD		
MOVABLE CORE		

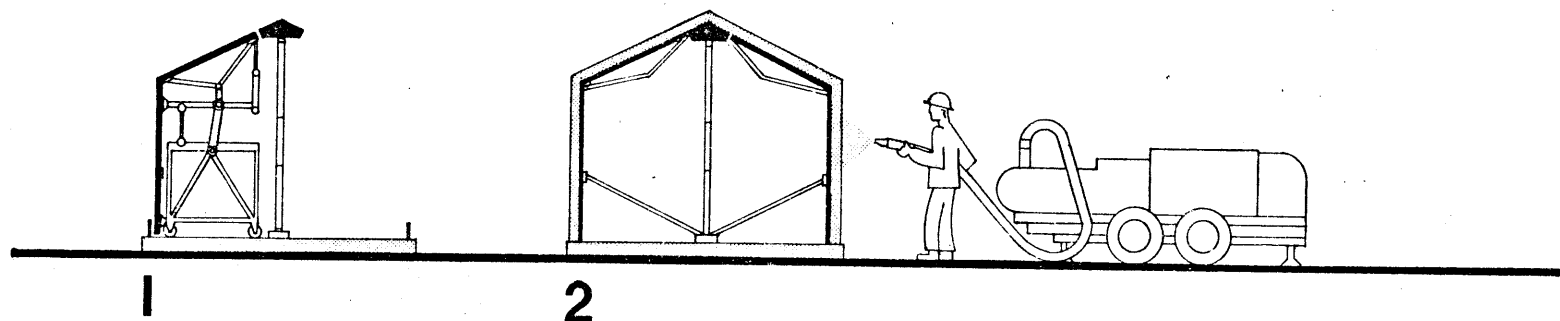
THE CONSPRAY METHOD

The Conspray machine system, invented by John Richards, was used in Brazil in 1973 to produce low cost on-site dwelling units at a rate of 4-6 dwellings per day with a single crew. It is now being used for low and high rise construction in the United States, including a 20-story condominium in Ocean City, Maryland.[39]

The example below shows the housing type developed for use in Brazil. Figure 1 shows a retractable steel form and center support placed on a previously poured floor slab. Welded wire reinforcing mesh is stretched over the steel form and attached to steel dowels extending upward at the edges of the slab.

Figure 2 shows a workman extrusion-spraying near-zero slump concrete to a thickness of 3" on the walls and roof. The concrete is troweled to the desired finish. After quick curing for 4-13 hours, the steel forms and supports are then retracted and rolled to a new position where the same procedure is repeated.

A prototype house has been cast using 1/2" waterproof gypsum board as stay-in-place forms with three-dimensional mesh attached on 12" centers. Concrete was sprayed to a thickness of 2-1/2" over the board. [40]



One wonders if this new technique (similar to gunite spraying) could over-ride the predicted economies of factory-produced concrete housing; or if this method could be introduced into the factory for box-unit production, for even greater cost savings and control.

Some of the advantages of the system which could be applied to factory-production of concrete box-units are:

1. There is no need for expensive forms except for casting the floor slab. One-sided forms are adequate and need not be heavily constructed because there is no hydrostatic loading on them as there is on two-sided forms. No form ties are needed, eliminating tie marks and labor required. Also, insertion of consolidating vibrators, often requiring thicker walls, can be avoided.
2. When used for box-units, the sprayed surface needs no additional troweling or finishing. (The redundant stacking boxes require only one smooth surface.)
3. Ready-mix concrete can be applied at the rate of 20 cubic yards per hour with a material loss of about 2-3%. This is a significant advance over gunite equipment rates.
4. Cold joints are eliminated because the force of the new material assures full bondage to the old concrete. Delays and work stoppages would not create concreting problems. Work is not limited to a specific number of wall sections which can be completed in one day.
5. Both in strength and appearance, the wall is indistinguishable from one cast conventionally, but it has no pockets or pits since the concrete is compacted against the form. Various form liners can be attached for a wide variety of smooth or textured surfaces.[41]

HISTORICAL NOTES

According to W. D. Tiner, P. E. "Mankind has been attempting to build low cost concrete houses for many years. In 1907, Thomas Alva Edison announced a 'new method of building dwellings of small cost.' [42] Edison said, 'There is nothing particularly novel about my plan: it amounts to the same thing as making a very complicated casting in iron, except that the medium is not so fluid. Someone was bound to do it, and I thought I might as well be the man, that's all.' Edison's announcement stirred up quite a controversy." [43]

"Over the next 14 years, more systems were proposed for the building of concrete houses. In 1921, H. A. Mount claimed that Simon Lake, of torpedo boat fame, 'has found and removed the flaws in Edison's plan.' [44] He, along with Robert C. Lafferty, a New York architect, developed an elaborate modular system that is very similar in many respects to that presently being used by H. B. Zachry Co. of San Antonio, Texas. Lake's house module was 12-1/2 ft. x 28 ft." [45]

"Lake's plan as stated was "...instead of building the house on the lot, necessitating a vast amount of labor for putting up and tearing down expensive forms, he will build monolithic concrete units from standardized forms in well-equipped factories, and deliver the finished house, ready for occupancy, to the lot." [46] This is

exactly what H. B. Zachry is proposing and has very nearly succeeded in doing economically. [47]

The first Russian ideas about box-units were expressed in 1901.

"In 1930, Prof. N. A. Ladovsky and architect E. V. Karaulov developed a new type of building with lightweight box-units to be inserted into the cells of the bearing frame. In the years which followed, a number of Soviet experts made suggestions about the application of ready-made three-dimensional elements of different types for housing construction." [48]

"In 1950, Le Corbusier developed the first multi-family structure in Marseille, France, using prefabricated boxes. His plan employed a huge ferro-concrete frame with rectangular slots into which 23 different types of apartments could be accommodated. Each of the 337 modules was prefabricated in the using dry construction methods. The overall cost of \$3 million in 1954 was compatible with conventional techniques." [49]

In 1955, three-dimensional monolith reinforced concrete sanitary units were manufactured in Russia for the first time.

The first experimental buildings using load-bearing concrete box-units were erected in seven Russian cities in 1958-1960. [50]

At first, Russian box-units were assembled from individual panels with welding of inserted details. This was found to be costly due to high labor consumption and difficulty of concreting the joints. Experiments with frame-box systems using reinforced concrete showed buildings could attain only 9 stories high and found only small production in Russia.

HABITAT '67, the first large box-system of its kind, was built for EXPO in Montreal, Canada by associated architects Moshe Safdie and David, Barott, & Boulva. Its story is well told in Moshe Safdie's book "Beyond Habitat", and in the engineers comments "Post-mortem on Habitat" in Progressive Architecture, March, 1968.

In 1969, plans were made by the Russian government for three new factories for construction in 1970; and soon after 25 specialized box-unit factories in varied regions. By 1973, 17,000 apartments (=800,000 sq. meters) using the reinforced concrete box=unit system.[51]

In 1971, the first building using the AUSA system was completed in Finland. According to Mr. Antero Salonen, two new factories are under construction. The system is patented in 10 countries and in the USA. Casting is done by placing interior and exterior forms on top of a previously cast floor slab. One unit weighs 40 tons and is lifted by a pair of 60-ton cranes. [52]

Dieter Meyer-Keller of the Institut für Industrielle Bauproduktion published a catalog of Box-unit types in 1972, entitled "RAUMZELLENBAUWEISEN--ENTWICKLUNGS-STAND UND TENDENZEN". It includes lists and descriptions of steel, wood, plastic, and concrete box-units.[53]

Twenty-one examples are described for box-units of reinforced concrete construction.

From Sweden:	Skanska
Switzerland:	Variel (Elcon)*
	Flex-bau
W. Germany:	Fels
	Ohl Ringzellensystem
Canada:	Habitat
Denmark:	Conbox
Holland:	Bouwvliet
Rumania:	Montaj
	Inst. of Concrete Const.
Spain:	SIC
USSR:	Belgos
	Giprograshdanpromstro
	#6 Moscow *
USA:	Diskin
	Uniment
	Zachry
	Habitat Puerto Rico
	I.I.T.R.I.
	Florida Prestressed
	Foldcrete

In addition, the BOSTADSBOLAGET BUILDING BLOCKS system of Sweden is interesting because it combines box-units containing kitchens and baths with concrete panel construction.[54]

AMERICAN FIRMS

It should be noted that SHELLEY SYSTEMS, INC. of 400 Park Ave. New York, N.Y. has ceased production building of multi-family housing and is concentrating on licensing its modular construction system to developers. The most recent licensee is the HOUSING DEVELOPMENT ADMINISTRATION of New York City. All told, according to Shelley, builders representing 2,000 apartment units are considering the system.[55] Shelley Systems was well known for its Operation Breakthrough participation and its checkerboard stacking pattern.

Only five firms in the USA which were making either box-units or box-and-panel systems recently have been located.

Only two seem to be successful and in production. The others are hoping for improvement in the economy and are concentrating efforts on overseas markets and licensing possibilities. Each firm is described briefly in the following section.

The firms are:

1. H. B. Zachry Company
2. Delcrete Corporation
3. Building Block Construction
4. Echo Group, Inc.
5. Allied General, Inc.

1. H. B. Zachry Company
Modular Construction Division
Design and Project Development
300 Tower Life Building
San Antonio, Texas 78205

The Zachry Company is well-known for the construction of the San Antonio, Texas Hilton Hotel, "Palacio del Rio" designed, completed, and occupied in an unprecedented period of 202 working days in 1968. Of the hotel's stories, the first four were built of conventional, reinforced concrete for support facilities; at the same time, an elevator and utility core were slip-formed to a full height of 230 feet. From the 5th floor to the twentieth, modules were stacked and connected by welding of steel embedments. The 496 room modules--each fully decorated and equipped at a plant eight miles from the site--were placed by crane in 46 days. A 350 h.p. crane equipped with a special 36 ft. diameter ring base and a 270 ft. boom maneuvered them into place. So that they could be literally 'flown' into place without turning or dangling in mid-air, a Sikorsky helicopter stabilizing tail section was attached to each room at job site. A maximum working tolerance of 3/4" was maintained." [56]

Since the hotel's completion H. B. Zachry, a world-wide construction enterprise has completed the following projects in its modular construction division created in 1970, entitled "Construction Modules, Inc."

A general office building--a fully equipped (4,000 sq. ft.) building designed for specific owners in San Antonio, Texas.

The 250-bed Metropolitan General Hospital in San Antonio, Texas--planned to reduce the required period of time for conventional methods 12-18 months; to obtain a 50% reduction in the interim financing, and among other assets to assure the capacity for rapid expansion with minimum interruption of patient care.

A seven-story addition to a hotel in Winter Park, Florida--ordered in mid-September, 1971 70 modular units were cast and finished by November 5, 1971 and shipped via rail to Florida. Four days later, after 1,500 miles of rigorous journey, the Zachry modules arrived safely at their final site, which was a hotel located near Disney World, Florida. The actual erection of the modules required six days. Total time for the operation: less than sixty days.

Five housing subdivisions, with more than 200 all-concrete homes, located in the City of San Antonio and in a Hill Country resort facing the LBJ Lake, convenient to Kingsland, Texas. For single family housing, the basic Zachry module design was modified--without any alteration in its structural composition--to achieve the traditional American gable look.

A 278-unit complex in Dallas, Texas, with a club, swimming pool, and maintenance facilities.

Current annual production was not noted on a recent questionnaire returned to me in November, 1974.

The H. B. Zachry Company is comprised of 9 subsidiary companies and 6 affiliated companies including 3 general contractors, 2 real estate developers, 3 materials suppliers, hotel and country-club administrators, an oil and gas company, an insurance company, a parking garage, and a railroad company.

Weight: 32-35 tons
Length: 29-32 ft.
Width: 13' overall
Height: 9' floor-to-floor
Tolerances: 3/4" for creep

A chase for utilities can occur between modules, internal to unit if 30" wide minimum. (Limited to 2 stories), or between units end-to end.

It is possible to stack up 22-modules maximum without any external structural members. For design purposes, the modules can cantilever a maximum of six feet, without any structural distress. A pre-cast ribbed slab system can be used to span areas between modules in increments of two feet to a maximum of twenty feet.

With a desired lead time of 60-90 days for design and production scheduling, 8 modules per day are finished under normal conditions. A maximum of 12 modules per day can be completed under special conditions with present facilities.

2. Delcrete Corporation
Ernest J. Delmonte, President
909 Linden Avenue
Rochester, New York

Although there has been no reply to my questionnaire, some information about this firm has been obtained from the March, 1975 issue of PB "Industrialized Building," p. 114.

The Delcrete Corporation was organized in 1971 after a two-year period of technical investigation which led to the conclusion that concrete was the desirable material with a relatively low cost scale, that factory machine procedures should replace hand labor, that a union shop would provide acceptance among site builders, and that the system would be applicable for hotels, hospitals, nursing homes, college dorms and apartments. Further analysis showed the need to provide more than a structural shell to justify the capital expense of a production plant and transporting system; so mechanicals, fixtures and furnishings are provided.

The room units are comprised of separate floor and ceiling slabs flat-cast in special beds with internal vibrating networks. For room walls, a reinforcing grid cage is assembled over the floor slab and plumbing-electrical runs are put in place along with interior door frames. The wall-casting machine is placed over the cage. After initial hardening, the machine is retracted and moved to the next station. A precast ceiling is placed and connected, and the room unit is moved to another location for fixtures and finishing. Waste, vent, and supply piping plus electrical conduit runs are pre-installed in the corridor

shaft between paired rooms. Removable precast panels are placed over the chases before shipment to the site. Depending on design requirements, closures for spaces between modules and at the roof are also provided. The 25-ton boxes may be stacked to 20 stories. The boxes require foundation supports at each end and in the middle.

The first Delcrete project using the precast box-units was finished in 1973. The three-story 101 Room Depot Motel in Pittsford, New York featured a mansard roof concealing mechanical installation and brick columns to cover air spaces between units.

Three motel projects for the Marriott chain have been completed, and other projects are being planned.

The latest project in Bloomington, Minnesota resulted in a savings of about \$2000/room, according to Marriott officials, not including the time saved and the fact that there was only minimal disruption of the existing inn's operations. (The greatest savings per room is claimed to be \$5000 or more.) Of special interest was the use of a rail transport system (not described) which made the 1,245 mile trip from the Rochester, New York plant feasible.

A one-time manufacturer of aircraft-missile generators, Delmonte is now owner of over 20 major industrial buildings in the Rochester area including the Rochester Marriott Inn, completed via the Delcrete system in 1974.

Mr. Delmonte, President of the Delcrete Corporation, was speaker at the December 10, 1974 INBEX Conference in Chicago, Illinois on the topic "Using Precast Boxes in Quality Motel Construction."

The firm is in a position to own and operate, own and lease, or to sell units to other companies and developers. The annual dollar volume of the firm is said to exceed \$8 million, in the fiscal year ending August 31, 1974.

3. Building Block Construction
3400 Edison Way
Fremont, California

This firm manufactured 500 multi-family units in 1973 and planned 750 units in 1974.

"The privately held corporation had an estimated sales volume of \$5 million in 1973. The company manufactures a reinforced concrete module that measures 12 ft. wide, 12 ft. long, and 8 ft. high. The system can be used up to 40 stories high. In addition to residential units, the company fabricates units for motels and commercial buildings. H. M. Hanson is president." [57]

According to Mr. Mitchell, an investor in the Building Block Construction Group, the firm began in 1968 starting from a background in aluminum products and mobile homes. In 1969, a 14-story apartment building was erected using their system for the Oakland, California Redevelopment Agency. A second project in Mountain View, featured 3-story townhouses. Another 6-unit, two story project was completed in 12 working hours, according to Mr. Mitchell.

Each 10-12 ton element is cast in a patented form. A rocking device turns the U-shaped mold over to form walls and ceiling. The 12' x 12' x 8' unit contains 1-1/2 tons of steel. Dimensions were chosen to coordinate with most 4' or 8' building materials. The electrical conduit is cast into 4" thick walls. Blackouts for doors and windows can be located where desired.

The firm purchases and installs its own bathroom components, kitchen cabinets and equipment. California Fire Codes dictate wall thickness above all other considerations, including structural requirements. Therefore, at the height when post-tensioning might be utilized, the walls are also required to be 6" thick for fire/code compliance.

Although the company is presently not producing the units, it has one licensee in Japan and other firms of countries are reportedly interested in the system.

4. ECHO GROUP, INC.
2455 E. Sunrise Blvd.
International Building
Ft. Lauderdale, Fla. 33304

The Echo Module system was developed by Architect Edgar H. Wood* after three years of research and development. Originally located in Quincy, Massachusetts, the main office is now in Florida.

The first application of the system is in Weymouth, Massachusetts, 12 miles south of Boston. The 'Weymouthport' project, completed in early 1974, consists of 261 apartments in six-mid-and 14 story high-rise buildings.

The Art Cement Products Company in North Wilbraham, Massachusetts, was licensed to produce all the concrete components for 'Weymouthport.' Their factory is 100 miles from the jobsite. (Transportation costs amounted to 24¢ per contact foot of concrete.)

Westinghouse was licensed to manufacture the three-dimensional kitchen, bathroom, mechanical, and elevator modules designed by Echo. (Westinghouse has since stopped producing these modules, for which it paid a royalty to Echo.)

*Mr. Wood offered a great deal of personal assistance by supplying detailed information about the ECHO systems and discussing implications of systems building.

The system is a hybrid one--combining both box modules and spanning planks as illustrated on page 142. Although not a true box-unit system, this system is of interest for its design flexibility.

The horizontal organization of the company and the design services offered have been mentioned earlier in this paper.

Basically, Echo is an assembly of precast concrete plates, beams and three-dimensional concrete facade modules complete with window or door frames, which are lifted into place and secured to form corridors, walls, and ceilings, and floors. The modules and plates combine into a structural unit. The plates vary in thickness from 4" to 8", and are classified as floor plates, plate column, or shear wall plate. The heaviest module weighed 26 tons.

Buildings up to five stories, because of their weight, do not require post-tensioning, while taller structures are post-tensioned.

On September 3, 1974, ECHO INTERNATIONAL, LTD. was formed, and since that time has entered into licenses in six countries. Their areas of interest for systems technology are all the Central American countries Spain, Africa, Portugal, and the Mid-East with the first project assured in Dubai on the Arabian Gulf. [58]

5. Allied General, Inc.
Princeton, Florida

According to Engineering News Record Magazine, the Allied General Company, Inc. has a contract to supply 100 of its newly developed concrete box-units to Southern Ventures of Miami for use on scattered sites in low-income areas of greater Miami.

The company utilizes a new technique of injection molding: incorporating a \$2 million machinery package including the molding unit and subsidiary equipment and a special 'rich cement mix' with patents pending. The smoothly flowing concrete makes possible the use of the injection molding process.

One machine and its ancillary equipment can produce six modules, or three houses per 24-hour cycle, using a regulated set cement. The concrete, containing 13 bags of cement per cu. yd. of concrete, as well as fine silica sand, chemical additives and binders, attains strength in 3 hours equal to that of a mix using ordinary portland cement after 12 hours. One machine can produce 500-700 complete houses per year.

Each module is 48 ft. long, 11.6 in. wide, and 11 ft. high and weighs 45,000 pounds or 22.5 tons. Two modules cost \$14,000 at the factory, \$400 for loading, and about \$1 per mile for transport. individually on a low bed trailer to the site. Each 3-bedroom house is formed from 2 units; both kitchen and bath are in one unit.

The floor is 6" thick, including 4" of foamed plastic insulation panel installed in the machine prior to injection of the concrete. The walls and roof are 4" thick, including 2" of insulating panels, which in the molding process become encased in the concrete. The modules are reinforced with No. 3 reinforcing bars. Panels, rebars and chases are installed in the machine manually, prior to the injection molding operation.

The modules are formed with openings for windows, exterior and interior doors and closets. After molding, the modules are moved on rails to another section of the plant where the windows, doors, bath and kitchen fixtures, plumbing, electrical services and interior partitions are installed.

At the site, two modules are placed on courses of concrete blocks. Tie rods are run through channels formed in the molding process: six in the floor and one in each end wall. Nuts at the ends of the threaded tie rods are tightened to pull the modules together. Then grout is hand-troweled at joints over a mesh placed in a 4" wide indentation cast into the units.

A dispute by Dade County officials who want the units certified under local codes and by state officials who administer the state-wide code on factory-built housing is holding up unit delivery.[59]

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TRANSPORTATION

RAIL TRANSPORT

Rail transport definitely limits a box-unit to 12 ft. wide; with careful routing necessary over 11 ft. to avoid narrow bridges and commuter trains.[1] If a load is 12 ft. wide, a load height of even 8 ft. compounds the routing difficulty. Flat car lengths must not exceed 89'-6" in length; the maximum load per car is 35 tons.[2]

Obviously, handling (loading and unloading from trucks) becomes costly when using rail-transport.

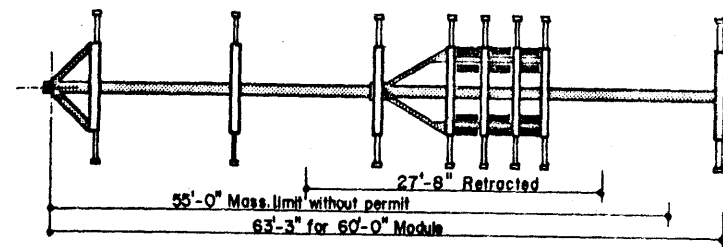
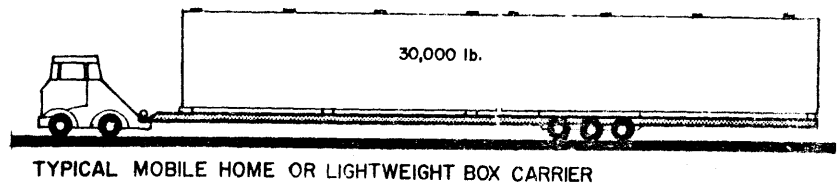
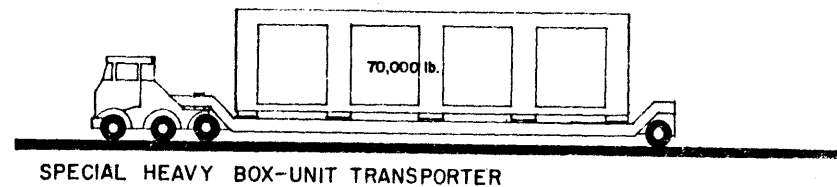
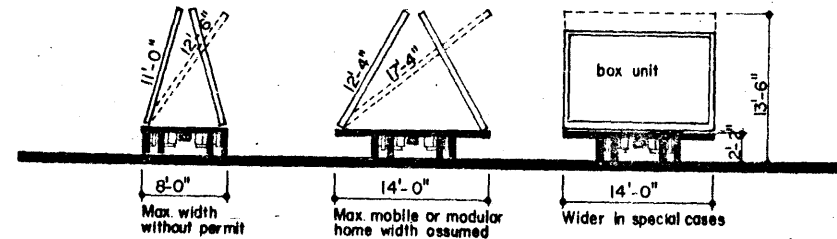
TRUCK TRANSPORT

Road transport must conform to the legal requirements regarding vehicles and their loads as set forth by the different states.

"The Industrialized Housing Feasibility Study" states the nine Northeast states limit no-permit loads to:

- 8' - 6" wide
- 55' -70' long (including cab)
- 13'6" high (from road bed)
- 36-40 tons gross weight

States allowing movement of 14 ft. modules on a lowboy are: Maine, Delaware, New Jersey, Maryland, North Carolina, Massachusetts and Georgia.[3]



As of March 1, 1973, 34 states permit movement of 14 ft. wide mobile homes. Texas and Wisconsin allow movement of 16 ft. wide mobile homes. [4]

This project assumes that 14 ft. wide transport of modules (box-units) will be nationally accepted in the near future. If exterior walls are attached to the box-unit, allowance must be made for the extra wall thickness.

The M.I.T. Study, "Industrialized Housing Feasibility Study" of 1971 states "...a manufacturer would be very unwise to base his production on box-units more than 12 ft. wide. Although at the present time permits to move such loads are obtainable, it may not be possible to do so under mass production conditions should such loads prove detrimental to traffic movement". [5]

Nevertheless, shipments of 14-ft. wide mobile homes now account for 30% of the homes shipped by manufacturers to retailers during July, 1974. [6]

The Automobile Association of America (AAA) uses some of its funds from the membership dues to lobby against large-loads permission.

OVERSIZE LOADS

In Massachusetts, loads over 55 ft. long or over 36.5 tons, or over 8 ft. wide require a permit, flag car(s) and/or police escort. The State does not charge for issuing the permit, but the carrier may charge \$10.00 for use of its telex machine which facilitates the release of the permit within 10 minutes of application. [7]

A permit is valid for two weeks. According to the Massachusetts State Department of Public Works, the largest loads to date in 1973 have been.

Longest:	170 feet
Widest:	25 feet
Heaviest:	60 tons gross

Loads may be restricted to 9:30 a.m. to 3:30 p.m. with no hauls Fridays or Holidays. Secondary roads and city roads present additional problems. The Chief of Police within a municipality must approve passage of oversized loads.

"Intrastate limitations are often placed on secondary roads. This has the effect of creating non-service pockets within a general market area. A solution is national guidelines for modular transport, as set forth by the Federal Highway Administration". [8]

HEIGHT

If the carrier assures the State Department of Public Works that the obstacles along the route have been measured for clearances or that bypass routes have been found, there are no limits on height in Massachusetts. Unfortunately, the office does not have a record of clearance under bridges or overpasses.[9] As is well known, some underpasses in the area of Cambridge are only 11'-0" clear.

A standard lowbed trailer has a platform only 26" from the roadbed. This allows a box-unit 11'-4" high with a total height of 13'-6".

Standard all-purpose truck trailers are usually 3'-3 1/4" to 3'-8 1/2" from platform to roadbed, allowing only 10'-2 1/2" for the unit.

The average concrete box-unit for multi-family apartments is usually 9'-0" high, but units with gabled or pitched roofs for single-family dwellings are sometimes desired, and are designed to maximum height allowed.

IN-HOUSE TRANSPORT

Although "rolling stock can constitute 15% or more of the capital investment required" [10] for a sectional-modular plant, there are definite advantages to in-house vehicles.

In the case of mobile homes, the drivers (usually two) become the erection crew for setting the unit upon its foundation. In-house transport allows for optimization of scheduling or deliveries, with one source of responsibility in case of damage. Costs may be better controlled.

In 1973, three of the largest mobile-home carriers, accounting for 85% of the business, were charged with price-fixing.[11]

H.B. Zachry Co. of San Antonio, Texas, uses a highway 'transporter' specially designed to carry 35-ton concrete units. Conventional heavy truck trailers can also be used, especially to areas close to the production plant at a maximum of 100 miles.[12]

Various trailers are available for transporting precast components, mobile home and concrete boxes.

According to a poll I conducted of about 125 firms in 1974, 36 firms replied. Of these, 24 firms or 66.7% provide in-house transport vehicles and drivers. [13]

TRANSPORTATION COSTS

The cost of transport is difficult to determine without first-hand experience. Moreover, costs are dependent upon distance, road and traffic conditions, wage rates, fuel rates, and costs of equipment.

According to one source, "...transportation is over-rated as a deterrent to factory house-building" and that "...the delivery charge to the fringes of a 300 mile radius from the central factory would approximate only 1.5% of retail price, and quite likely would average somewhere in the 1.0% range".[14]

Using data from the MOBILE HOUSING CARRIERS CONFERENCE, the M.I.T. Study of 1971 concluded that heavy-weight concrete boxes could be transported at a cost of 50 cents per square foot, whereas lightweight steel or wood box systems could be transported at 29 cents per square foot; for the first 100 miles.[15]

According to a recent survey by the NAHB, The average modular producer ships an average of 170 miles at a cost of \$1.41 per mile. This amounts to 6.7% of net sales.

The average panel manufacturer ships 115 miles with costs of \$1.26 a mile, amounting to 5.5% of net sales for delivery transport.

The survey also showed that volume producers, who try to stay price competitive in distant markets, don't pass on all shipping costs. [16]

For concrete panel systems, SAN-VEL CONCRETE CORP. made comparative cost studies of shipping panels and slabs from their Littleton, Mass. plant to New York City, a distance of 200 miles. They concluded that truck transport was cheaper and more reliable than either rail or water transport.[17]

According to the M.I.T. 1971 "Industrialized Housing Feasibility Study", European transport costs reached 3 to 3 1/2% of total construction costs with an economic radius of 25-60 miles. [18]

However, Fritz Stuckey, developer of the 3-D Variel (ELCON) System in Switzerland, operates in a 250 mile radius in Europe "...that covers a bigger market potential than it would in the United States." [19] Tables compiled by his firm are shown on the opposite page comparing the Variel System with large panel concrete systems in Europe.

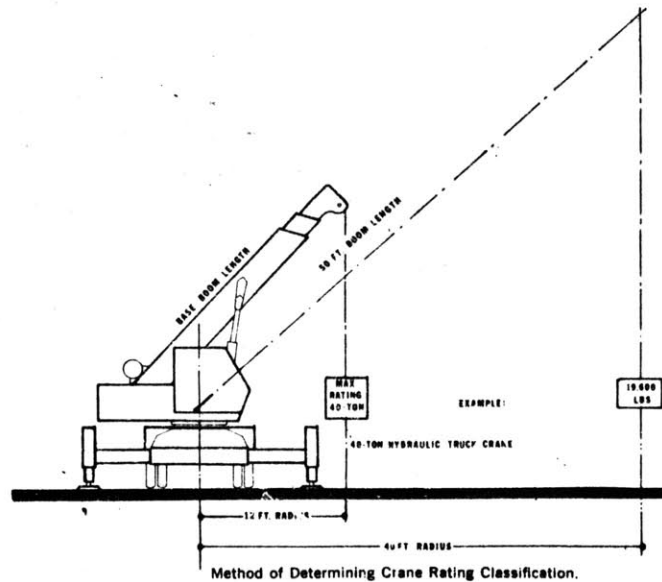
The difference in cost between U.S. and European transport may be due to "slower, more congested conditions of European roads, the higher cost of gasoline and oil, and the fact that the cost of rolling equipment is a higher proportion of total capital investment....." [20]

According to Mr. Stuckey, "The economical radius from the factory does not depend solely upon weight. More important is the value of the load. In other words, the transport cost, expressed in percentage of the building costs, are much lower if a unit including 25 m² of factory-finished building is shipped, rather than the same weight in two or three panels--as in large panel construction." [21]

VARIEL SYSTEM COMPUTATIONS FOR
TRANSPORT COSTS AS A PERCENTAGE OF
BUILDING COSTS:

Distance from Factory	VARIEL SYSTEM	LARGE PANEL SYSTEMS
50 km	1.2 %	5 %
100 km	2.4 %	110 %
150 km	3.6 %	15 %
200 km	4.8 %	20 %
250 km	6.0 %	25 %
300 km	7.2 %	30 %

CRANES



7.12.1 Rated Loads—(See par. 7.03 [1]) Lifting crane rated loads at specified radii shall not exceed the following percentages of tipping load (par. 7.01.3) at specified radius:

- | | |
|----------------------------------|-----|
| (1) Crawler mounted machines | 75% |
| (2) Rubber tire mounted machines | 85% |
| (3) Machines on outriggers | 85% |

Rated loads shall be based on the direction of minimum stability from the mounting, unless otherwise specified. No load shall be lifted over the front area of a truck mounted crane, except as approved by the crane manufacturer.

7.12.2 Classification, applicable to cranes with boom length of 50 feet or greater—lifting cranes shall be classified by a symbol consisting of two numbers based on crane rated loads (Par. 7.12.1) in the direction of least stability, with outriggers set if the crane is so equipped.

- (1) The first number of the group shall be the crane rating radius, in feet, for the maximum rated load, with base boom length.
- (2) The second number of the group shall be the rated load (expressed in pounds divided by 100, and rounded off to the nearest whole number) at 40-ft. radius, with 50-ft. boom length.

Example. — To illustrate the above method of classification, assume a truck crane rated 40 tons at 12-ft. radius with base boom length, and 19,600 pounds at 40-ft. radius with 50-ft. boom length. The classification of this crane would be:

"40-ton truck crane (Class 12-196)"

The number 12 represents the radius, in feet, for the 40-ton rated load, and the number 196 represents the rated load in pounds, at 40-ft. radius, divided by 100.

Source: PCSA MANUAL "1974 Mobile Crane Standards #2"

This section describes the basic types of cranes which could be used to move and lift box-units. An attempt was made to locate the crane with largest capacity of its type.

As shown on pages 118 and 119, the maximum load which can be lifted by a Liebherr 1250 C Tower crane is 33 tons or 66,000 pounds. This probably means a 33-ton box-unit should be the upper limit.

A cost and availability study would further define the optimum weight for a box-unit, but this is beyond the scope of this thesis. Perhaps only a contractor would have access to any reliable information with regard to fluctuating rental rates and availability of crane types in any one project area. Then estimates would have to be made to determine the composition and scheduling of the crew.

A survey of the manufacturers of cranes in the USA and Canada showed that new models introduced within the last year or two have greatly increased capacity.

The American Sky-Horse attachment on a crawler mounted basic crane was found to be the type utilized by Shelley for the construction of the concrete staggered box-system and by ECHO for construction of the Weymouthport project. However, the AUSA concrete box system in Finland prefers to use two small cranes, one on each end, for greater flexibility. (See page 93)

The basic crane types shown here are:

1. Crawler-mounted cranes
2. Truck cranes, including mobile self-erecting hydraulic cranes.
3. Tower cranes
4. Gantry cranes (Goliath cranes)

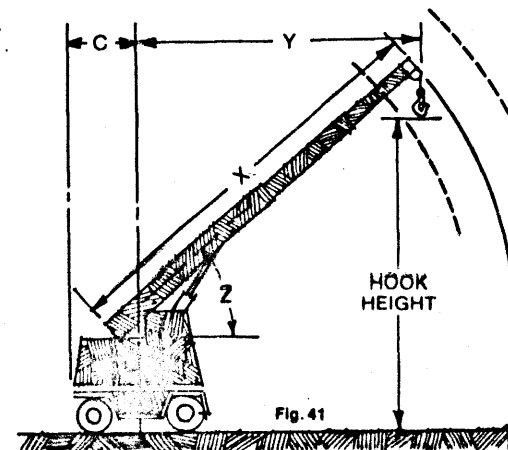
CRANE SELECTION

what size crane to use

When choosing a hydraulic crane for a job, it is important to determine the weight to be lifted, the radius and boom length required for the lift, and that these factors fall within the capacities specified by the manufacturer for the model crane being considered.

Rated lifting capacities of hydraulic cranes depend on:

1. Operating Stability - Whether the lift will be made on outriggers (as is normal) or on the tires only. Full outrigger stance is required for lifts approaching maximum capacity of the crane. Terrain should be level and firm.
2. The manufacturer's chart of rated lifting capacities is based on structural and mechanical limitations of the machine handling freely-suspended loads, and by the stated percentage of tipping (moment at which crane load begins to overcome level stability). Use of jib extensions affects capacity, and the jib capacity chart should be consulted. Rated capacity drops in proportion to any increase in working radius. Condition of the wire rope should be checked periodically, especially when approaching maximum capacity loads.
3. Counterweight - Since manufacturers rate lifting capacities by radius, use of counterweights is usually mandatory for safe lifts. The fulcrum distance is the distance between the front and rear outrigger midpoint, and the center of gravity of the crane's counterweight.



C SWING CLEARANCE (RADIUS OF REAR END FROM AXIS OF ROTATION)

X BOOM LENGTH PIN-TO-PIN

Y RADIUS OF LOAD

Z BOOM ANGLE

Crane operating and clearance dimensions are shown

Source: PCSA MANUAL, "Hydraulic Excavators and Telescoping-Boom Cranes," p. 20.

A wide variety of such working tools as crane hooks, magnets, tongs or buckets, may be used with the crane boom. These attachments will be applied most effectively by first determining the following job factors:

1. Type of load
2. Size and shape of load
3. Load weights in relation to basic unit capacity
4. Location and movement of load (from where to where)
5. Height of lift
6. Radius of work zone
7. Clearance for boom and rear end
8. Ground clearance
9. Overhead clearance (wires, etc.)
10. Ground condition

The Type of Load to be Handled —

Most loads are readily classified into solids, semi-liquids such as concrete, and bulk materials such as sand and gravel. The physical state and shape of the load indicate the most suitable tool to use. For example, a crane hook is commonly used with a sling if the load is an I-beam, a crate, a boiler, a stack of lumber, machinery or a stone slab. A concrete or skip bucket (with crane hook arrangement) is used to handle semi-liquid material. Clamshell or similar buckets generally are used for digging and for handling bulk materials. Grabs, grapples, tongs and clamps find their greatest use in handling materials that are more or less regular in size and shape, such as pulp logs or sheet metal.

The Size and Shape of Load —

This is an important factor in determining necessary clearances. Large bulky loads require greater clearances than small concentrated loads to avoid damage to surrounding structures. Load interference with boom, often the cause of boom failure, must be prevented.

Load Weight —

Load weight has a direct relation to the capacity of the basic crane. Thus it is imperative to accurately determine that the weight of the load, including slings, spreader bars, etc., is within the limits specified by the manufacturer for the specific boom length and radius required, before proceeding with the lift. Footing for cranes must also be considered, since cranes operate under a wide variety of conditions.

Location of Load —

Distance of move and the possibility of repetitive lifts must be considered when positioning the basic unit and determining the boom length required.

Height of Lift Dimension —

It is necessary to know the height of lift to determine the length of boom and the position of the basic unit.

Radius of Work Zone —

This is the area the basic unit can serve with a given boom length.

Clearance for Boom —

Clearance for boom point and rear-end swing must always be allowed when lifting in confined quarters or near wires and other overhead obstructions.

Ground Clearance —

In order to plan an efficient work cycle and avoid hazards, it is necessary to consider clearance between the machine and both natural and man-made obstructions on the ground.

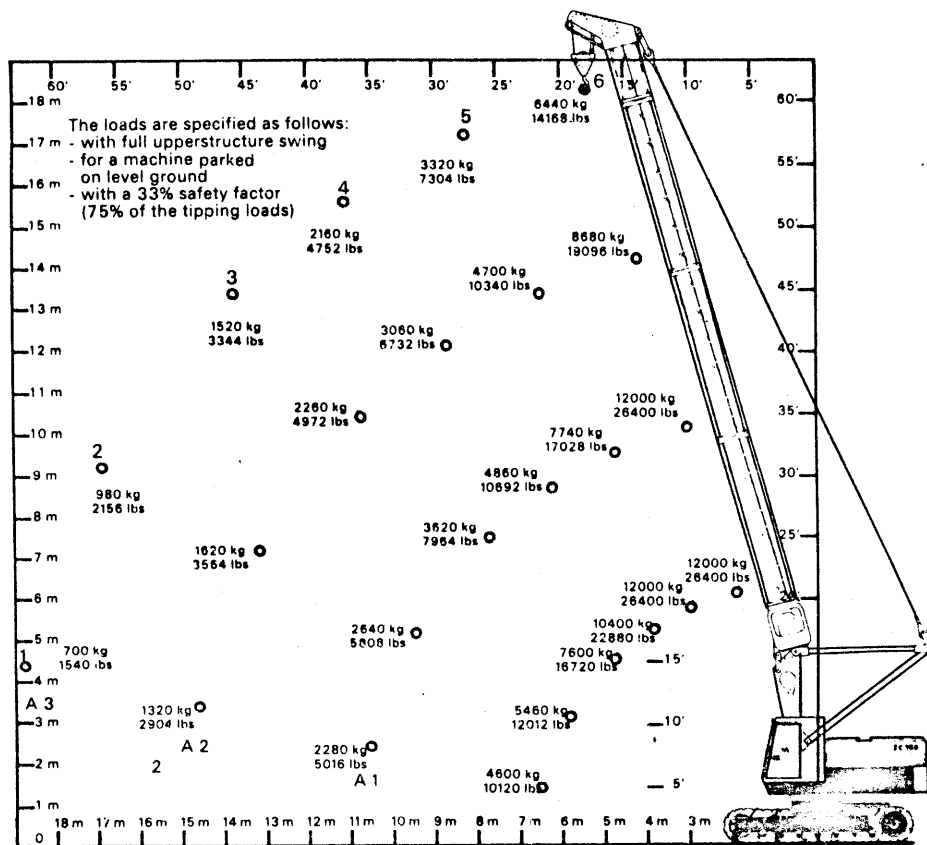
Overhead Clearance —

When setting up a crane, sufficient overhead clearance must be allowed between the machine and overhead wires, structures or other overhead obstructions.

Ground Condition —

Manufacturer's capacity charts are based on a machine resting on firm, level ground. In the best interests of operational safety and overall efficiency it is absolutely essential to check ground conditions, particularly the stability of the terrain, making allowances for soft ground conditions.

An example of decreasing load capacity
with increasing distance from axis.



Source: American Poclain Corp.
300 S.Randolphville Rd.
Piscataway, N.J. 08854
Poclain Crane Attachment D 150 04 74

Typical Load Table*

Radius in Feet	Boom Length in Feet										Power Pin. Fly & 141 ft.	32ft. Ext. & 173 ft. 2nd Offset
	*46	58	70	82	94	106	118	130	141	**173	**205	
12	250,000 (71.5)	120,000 (75.7)	118,500 (78.2)									
15	200,000 (67.3)	120,000 (72.5)	116,300 (75.6)	112,900 (78.2)								
20	150,000 (59.9)	120,000 (67.1)	101,500 (71.3)	94,350 (74.6)	90,550 (76.9)	87,600 (78.8)						
25	118,000 (51.8)	100,000 (61.4)	89,000 (66.8)	81,100 (70.8)	76,950 (73.7)	73,850 (76.0)	69,950 (77.9)	65,450 (79.5)				
30	95,000 (42.3)	85,300 (55.3)	78,400 (62.1)	71,100 (67.0)	66,750 (70.5)	63,600 (73.2)	59,900 (75.4)	55,800 (77.2)	53,150 (79.3)			
35	78,500 (30.0)	74,000 (48.6)	69,200 (57.2)	62,600 (63.0)	58,900 (67.1)	55,750 (70.3)	52,200 (72.8)	48,350 (74.9)	45,450 (77.2)			
40		64,850 (41.0)	61,200 (51.9)	54,700 (58.9)	52,650 (63.7)	49,450 (67.3)	46,050 (70.2)	42,500 (72.5)	39,300 (75.0)	35,000 (78.6)		
45		54,160 (31.6)	54,150 (46.2)	48,300 (54.5)	46,900 (60.1)	44,350 (64.3)	40,700 (67.5)	37,700 (70.2)	34,250 (72.9)	33,350 (76.9)	21,500 (80.0)	
50		46,030 (17.2)	46,030 (39.7)	43,050 (49.8)	41,800 (56.4)	40,100 (61.1)	36,250 (64.8)	33,650 (67.7)	30,100 (70.7)	29,500 (75.1)	19,900 (78.7)	
60			31,720 (21.6)	31,720 (39.2)	31,720 (48.3)	31,720 (54.5)	29,250 (59.1)	27,100 (62.7)	23,600 (65.2)	23,400 (71.6)	16,850 (75.8)	
70				22,670 (24.4)	22,670 (38.8)	22,670 (47.1)	22,670 (53.0)	21,850 (57.4)	18,700 (61.5)	18,850 (68.0)	14,600 (72.8)	
80					17,010 (26.3)	17,010 (38.6)	17,010 (46.2)	17,010 (51.8)	14,900 (56.5)	15,300 (64.2)	12,850 (69.7)	
90						12,600 (27.7)	12,600 (38.5)	12,600 (45.5)	11,900 (51.2)	12,500 (60.3)	11,450 (66.6)	
100							8,840 (28.8)	8,840 (38.4)	8,840 (45.3)	10,200 (56.2)	10,050 (63.4)	
110							5,500 (12.1)	5,500 (29.8)	5,500 (38.7)	8,280 (51.9)	8,200 (60.1)	
120								2,660 (16.6)	2,660 (30.7)	6,660 (47.3)	6,620 (56.6)	
130										5,040 (42.2)	5,260 (53.0)	
140										3,260 (36.4)	4,100 (49.1)	
150										1,600 (29.5)	3,080 (44.9)	
160											1,980 (40.4)	

NOTE: Boom Angle (degrees)
required for given lift
appears below the load
capacity in pounds.

SOURCE: GROVE MFG. CO., SHADY GROVE, PENN. Form 1054-175-15 M

*Grove TM 1275 PCSA CLASS 12-649

CRAWLER MOUNTED CRANES

Crawler mounted cranes have the largest capacity of cranes which can also transport loads and move about at the site.

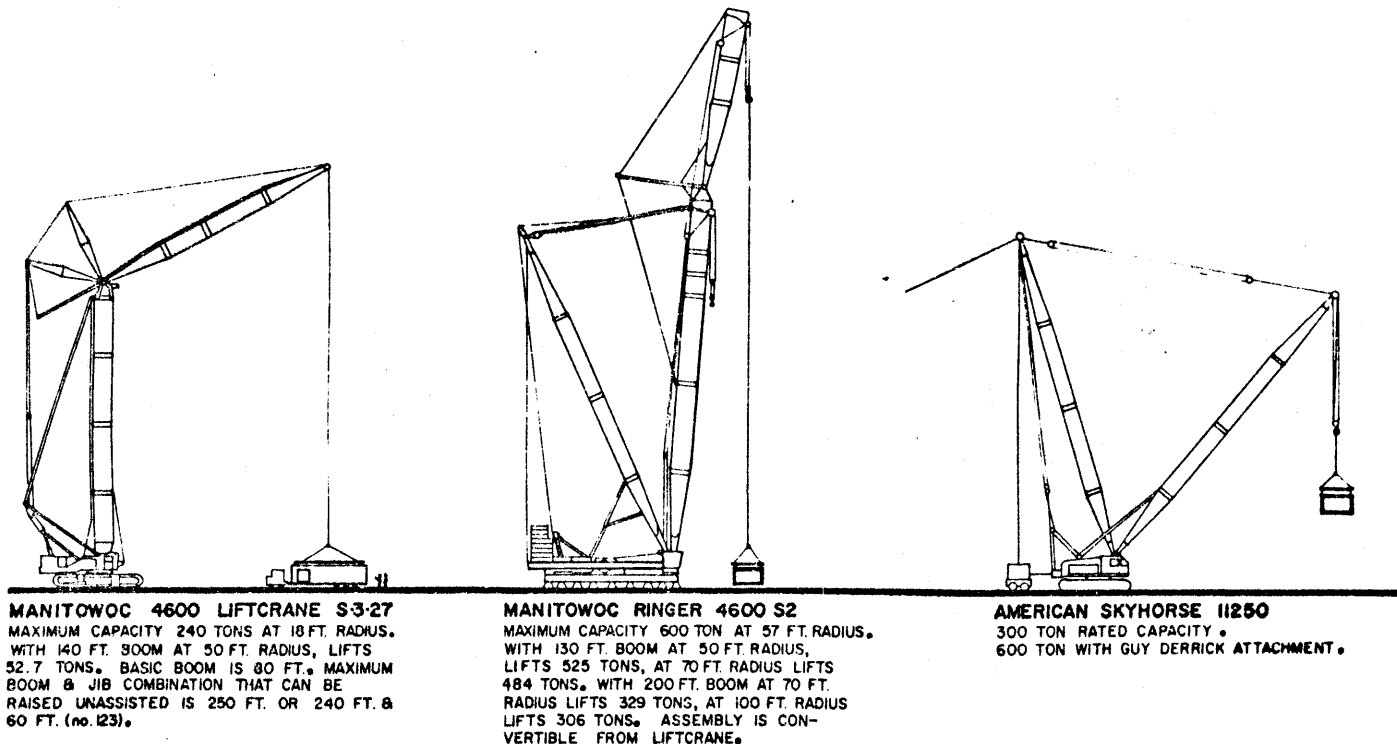
The crawler mounting available from most manufacturers fits most conditions and attachments for pile driving, digging, and dredging. The crawler crane is superior on soft or wet ground to any other crane type.

The cranes shown below are examples of the largest capacity equipment which I could obtain from manufacturers' literature.

Skillful operation is necessary to maintain stability. When loaded, the crane is allowed to move only horizontally and on sufficiently load-bearing ground.

Because the crawler crane has a speed of only 2 mph and may damage paving, it cannot travel long distances and must be transported from job to job on a flatbed trailer.

Attachments such as the Guy Derrick for the American 1100 Crawler Crane increase the stability and load capacity of the basic crane ten times up to a rated capacity of 600 tons.

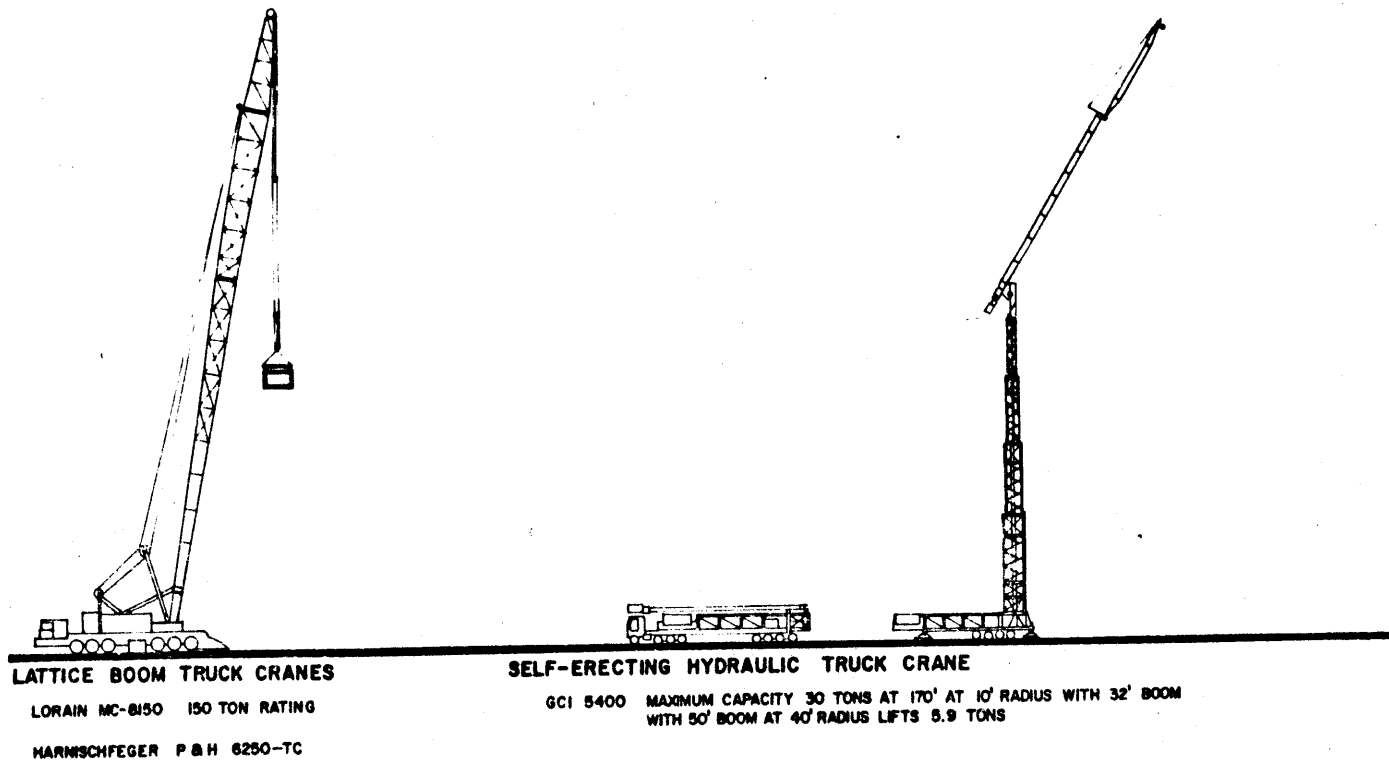


TRUCK CRANES

Truck cranes are the most efficient of all cranes due to their mobility--able to travel on the highway on their own wheels at speeds up to 50 mph. Multiple axles and dual flotation enable use as "off-highway" units not limited to hard roads. Outriggers are used for stability.

Many types of truck cranes are available. Self-assembling fully hydraulic mobile cranes are of special interest for their speed of erection.

Truck cranes do not attain the large lifting capacities of crawler cranes. Truck cranes range up to about 150 tons of rated capacity.



TOWER CRANES

ADVANTAGES

Economical if a great number of members is to be hoisted.

Able to perform three kinds of movements at the same time: to hoist the load, to move backwards and forwards, and to turn together with the load on the boom. The boom of certain tower cranes is furnished with a travelling crab which would be a fourth kind of movement.

Circular tracks are possible.

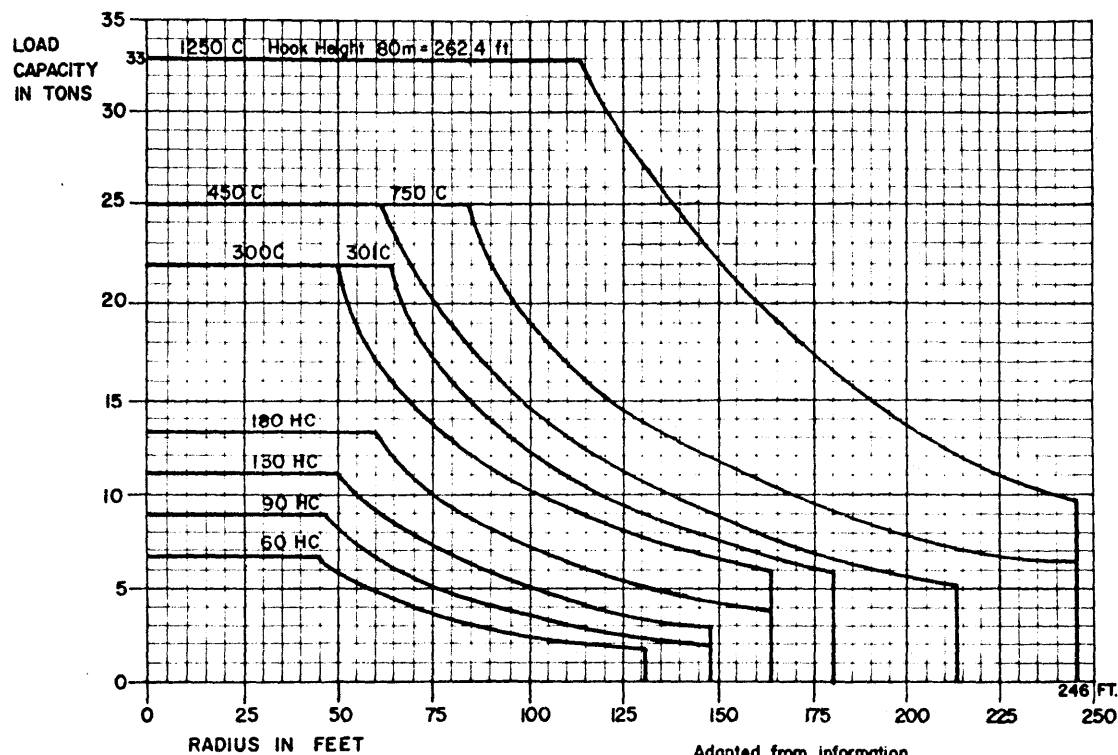
The load capacity curve is constant to a large radius. For example, the LIEBHERR 750C can maneuver a 25 ton load from 0 ft. to 85 ft., indicating efficient machine usage for that load.

DISADVANTAGES

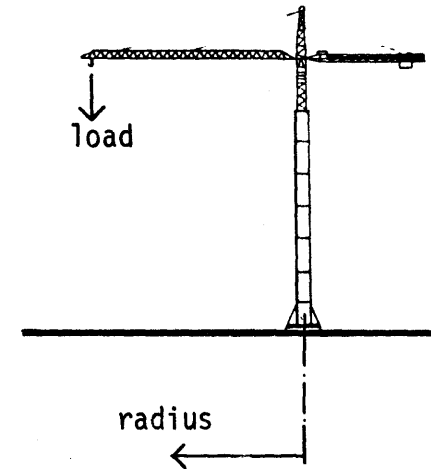
Requires a heavy rail track resting on a proper foundation, unless the model is light or a self-assembling crane.

Cumbersome, lengthy, and expensive assembly, dismantling and shipping.

RANGE OF LIEBHERR TOWER CRANES



Adapted from information
courtesy of LIEBHERR Crane Corp.



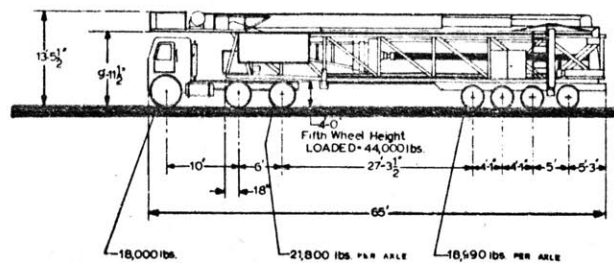
The maximum hook height
of the 1250 C Liebherr
Tower crane is 262.4 ft.

Hook heights for other
crane types are not
shown here.

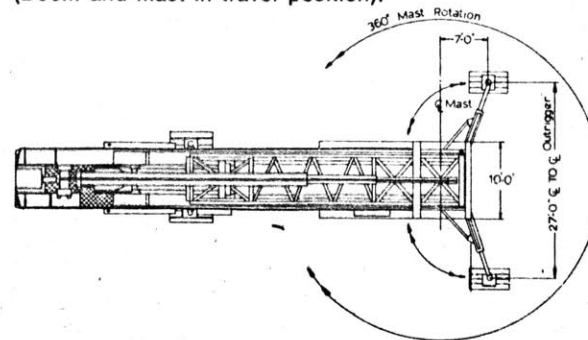
AN EXAMPLE: A Hydraulic Crane

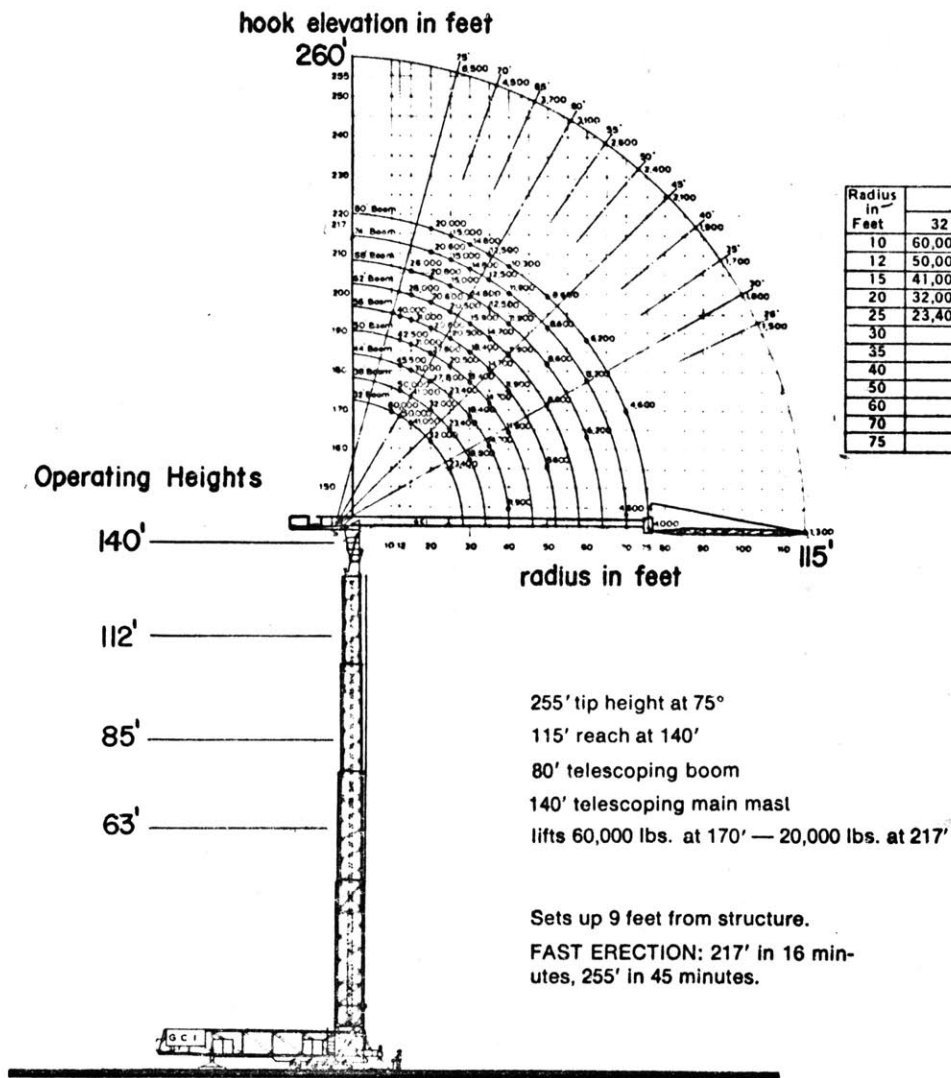
The GCI 5400 is a completely mobile self-erecting hydraulic crane. In tractor-trailer configuration it travels at a highway speed of 50 mph. The 40 ft. jib, blocks and all rigging are mounted on the crane. Once outriggers are set, the main mast erects hydraulically from horizontal to vertical position and telescopes to operational height in minutes.

Crane in travel position.



Crane with outriggers in position.
(Boom and mast in travel position).





RATED LIFTING CAPACITIES IN POUNDS
OUTRIGGERS FULLY EXTENDED
LIFTING CAPACITIES — 360°

Radius in Feet	Boom Length in Feet							
	32	38	44	50	56	62	68	80
10	60,000							
12	50,000	50,000	45,500	42,500	40,000			
15	41,000	41,000	31,000	31,000	31,000	28,000	26,000	
20	32,000	32,000	27,800	27,800	20,600	20,600	20,600	20,000
25	23,400	23,400	23,400	20,500	20,500	20,500	15,000	15,000
30		18,800	18,400	18,400	15,900	14,800	14,800	14,800
35			14,700	14,700	14,700	12,500	12,500	12,500
40			11,900	11,900	11,900	11,900	11,900	10,300
50					8,600	8,600	8,600	8,600
60						6,200	6,200	6,200
70							4,600	4,600
75								4,000

All capacities are based on structural strength and do not exceed 66⅔% of the tipping load, in accordance with SAE J-765 and SAE J-987.

JIB CAPACITIES IN POUNDS
 40 ft. JIB No Offset

Boom Angle	Rated Load	Radius in Feet
75°	6,500	27
70°	4,500	36
65°	3,700	46
60°	3,100	56
55°	2,600	65
50°	2,400	73
45°	2,100	80
40°	1,900	88
35°	1,700	95
30°	1,600	99
28°	1,500	104
0°	1,300	115

Source: General Crane Industries, Ltd.
 670 Industrial Road, London, Ontario

GANTRY CRANES

Gantry Cranes are used for transporting loads up to 60 tons over short distances. Their main use is in yards of manufacturing plants moving heavy elements to storage or transportation depots. More universal use is restricted due to their large size and slow speed of 3 mph or about 90 ft. per minute up a maximum slope of 7%. Their lifting height is limited to about 50 ft. on the largest model (shown opposite).

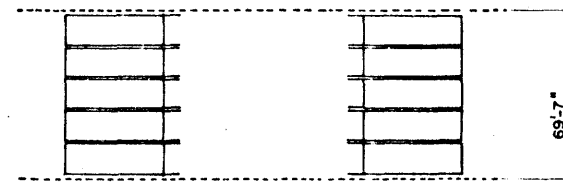
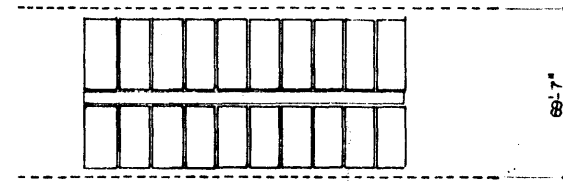
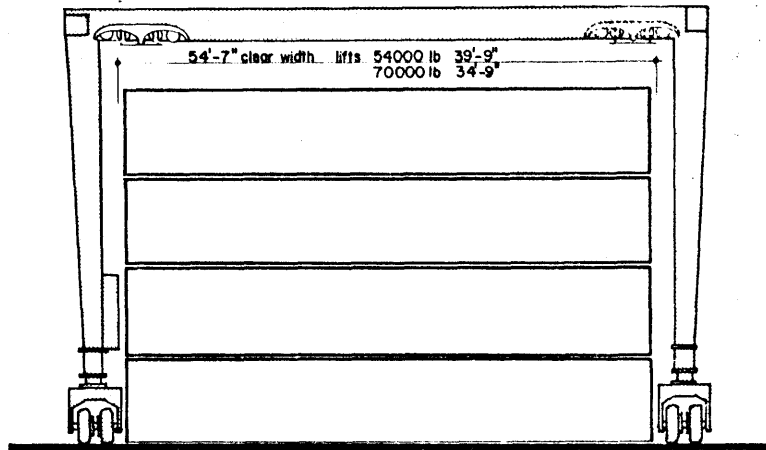
If means could be found to easily dismantle or transport the crane, its size and stability would be adequate for erecting row-housing. The model shown is assembled by bolting the erection joints of the welded steel frame. Various attachments are available.

The Gantry Crane is sometimes termed a 'Goliath' crane; it is not to be confused with the gantry attachment of a basic crane used to increase capacity.

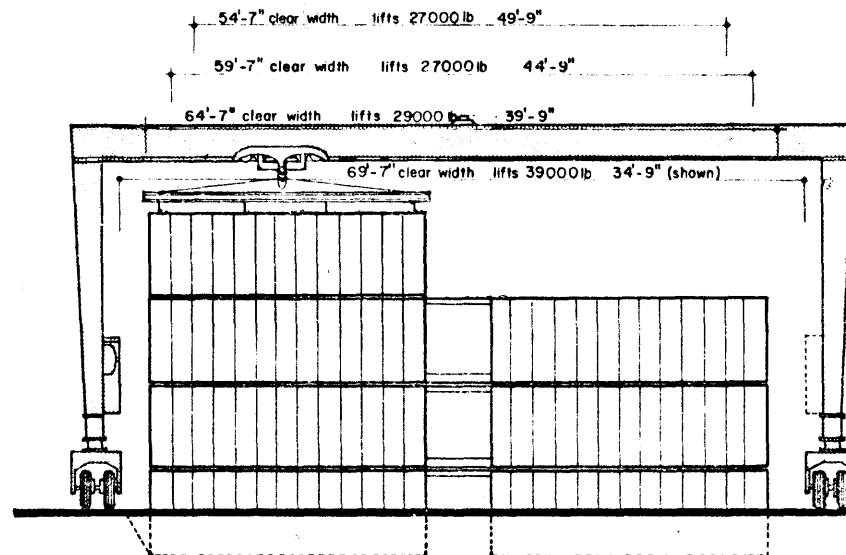
DROTT TRAVELIFT 1000 AI LIFT CAPACITY CHART

Capacity vs. Vehicle Dimensions												
Height to Hook Saddle	INSIDE CLEAR WIDTH											
	19'7"	24'7"	29'7"	34'7"	39'7"	44'7"	49'7"	54'7"	59'7"	64'7"	69'7"	
19'9"	120000	120000	120000	120000	120000	120000	120000	120000	116000	100000	85000	
24'9"	120000	120000	120000	120000	120000	120000	120000	112000	94000	79000	65000	
29'9"	120000	120000	120000	116000	113000	109000	105000	90000	74000	60000	47000	
34'9"	120000	120000	120000	113000	113000	101000	83000	70000	56000	42000	39000	
39'9"	120000	120000	120000	110000	100000	82000	65000	54000	42000	29000		
44'9"	120000	120000	113000	95000	79000	65000	51000	39000	27000			
49'9"	120000	118000	97000	80000	65000	50000	37000	27000				

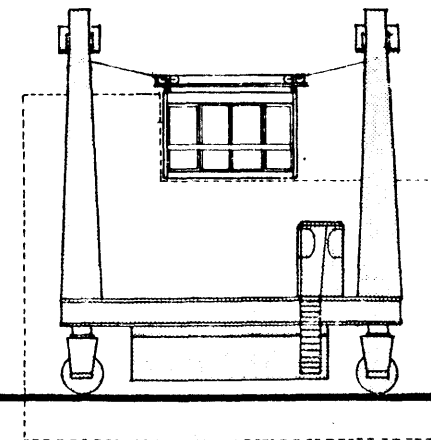
Courtesy DROTT Manufacturing 1974



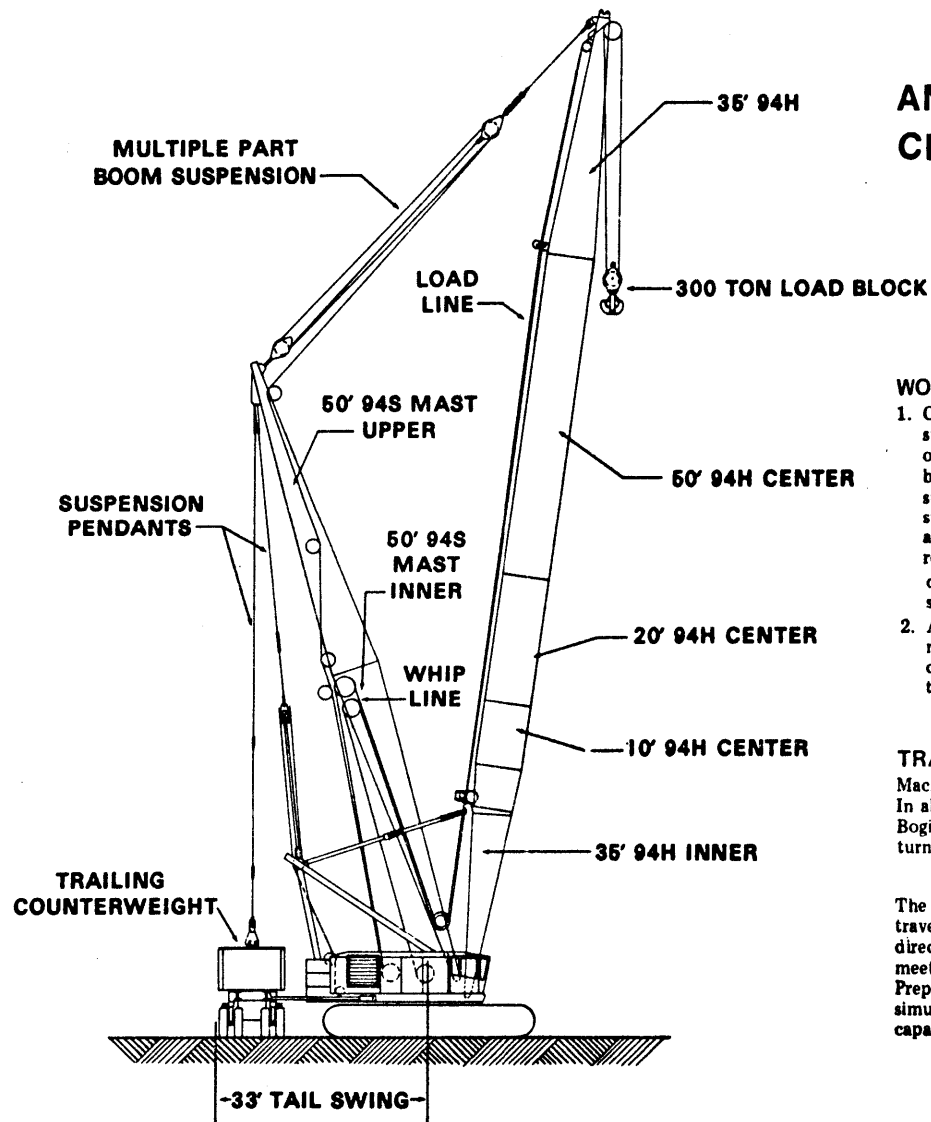
TOWNHOUSES ERECTED BY A GANTRY CRANE
(Drott "Travelift" 1000 AI)



DROTT TRAVELIFT 1000 AI front view



side view



AMERICAN SKYHORSE CRAWLER CRANE 1100

WORK SITE PREPARATIONS

1. Crawler tracks must rest on firm uniformly supporting surface such as concrete slab or sound timber mats placed on compacted soil and extending a minimum of 3 feet beyond each side of the crawler tracks. This entire bearing surface must be level within 1 inch and must have sufficient stability to remain within this tolerance when subjected to a load of 655 tons at 4.52 foot radius from the center of rotation. This is equivalent to a maximum bearing pressure of the track pads on the support surface of 186 psi (60 inch shoes).
2. A 12-1/2 foot wide path having an outside radius of 34 feet must be level ± 3 inch with the surface supporting the crawler treads. Path must be long enough to accommodate the boom swing arc.

TRAVEL

Machine may travel without load on grades up to 10 percent. In all traveling conditions, the swing must be left free to float. Bogie tires are normally aimed straight ahead, but may be turned to position the boom.

The SKY HORSE is capable of travel with rated loads. When traveling with maximum rated capacities, the load is suspended directly over the front of the machine and the surface must meet the level and stability requirements of "Work Site Preparation." Travel with the load in other positions or simultaneous swing and travel is possible with 90% of the rated capacity provided the same conditions are met.

Lifting capacities of the AMERICAN Model 11250 crawler crane is increased up to 400% with the addition of the Sky Horse attachment. Boom and jib combinations to 460 feet are available. When shipped from the factory with the Sky Horse attachment, the machine is equipped with a modulated clutch torque converter, controlled load lowering and single lever control on auxiliary hoist drum, supplemental trailing counterweight with suspension pendants, and 94 inch cross section boom and mast with suspension rope and pendants.

TRAILING COUNTERWEIGHT: The Sky Horse trailing counterweight is pin connected to the rotating machinery deck of the crane and is attached to the mast tip by adjustable pendant lines. The counterweight tank is filled with sand to obtain the required weight of 200,000 pounds. Four sets of dual wheels are positioned hydraulically. Counterweight connecting bar is cross braced for rigidity.

COMBINATION BOOM: Basic Sky Horse boom is 150 feet long and consists of a 35 foot 94H inner, 10, 20 and 50 foot 94H centers, and a 35 foot 94H outer, which has six offset sheaves. All sections of this pin connected 94 inch cross section boom are constructed of tubular T-1 steel chords and tubular lattice. One additional 50 foot 94H center section and three 50 foot 94S center sections are utilized to obtain a maximum length of 350 feet. The 1100 Series 600 ton Guy Derrick attachment also utilizes this same boom. All sections, except the 50 foot 94H centers, are used for the standard Lift Crane boom.

SKY HORSE MAST: The basic 100 foot 94 inch cross section mast consists of a 50 foot inner section which is mounted in the upper boom foot and a pin connected 50 foot mast tip. The inner section contains guide sheaves for the load and whip line. The mast tip has three boom suspension line sheaves and equalizer mounting brackets for counterweight pendant. Mast height is extended to a maximum of 180 feet with the addition of 10 and 20 foot 94H, and 50 foot 94S center sections with matching pendants. All mast sections and pendants are pin connected for quick assembly. These same mast components are also used for the Guy Derrick attachment.

ERECTION PROCEDURE FOR SKY HORSE:

1. Assemble the 1100 at the site in the usual manner — as a standard lift crane without a boom. Raise A-frame to special Sky Horse position. Assembly "Sky Horse" mast of the required length at a convenient place alongside the machine or in front of the machine.
2. With outside assistance, install the mast into the upper boom foot seat. Reeve mast suspension ropes and blocks. Place the counterweight pendants along the top of mast bail. Raise mast about 5 feet above ground and reeve the boom suspension rope and blocks.
3. Using mast as a boom and derricking lines as a load line, assemble boom length required alongside of machine.
4. Swing machine 180 degrees, and using mast as a boom and derricking lines as a load line assemble the counterweight trailer and tank directly behind the crane with the connecting arms blocked up about 3-1/2 feet above ground. Do not install ballast at this time.
5. Swing the crane 180 degrees and back the machine into the trailer, gradually raising the connecting arms into place as it clears the bottom of the crane counterweight. Insert trailer attachment pins and install trailer tie rods.
6. Using mast as a boom and derricking lines as a load line, raise the boom and install it in the lower boom foot seat.
7. Boom out, and connect outer derricking block to boom tip. Raise mast to nearly vertical position. Continuing to take up mast lines and pay out derricking lines, until top of mast is over the counterweight tank. Attach the counterweight pendants to tank ears and fill tank with ballast. Pay out mast lines and take up derricking lines until counterweight pendants are taut. Raise boom point about 5 feet off the ground and reeve main load fall.
8. Using derricking lines only, raise boom to a position approximately 45 degrees above horizontal. Machine is now ready to walk to the work site.

Operator's Instructions available upon request.

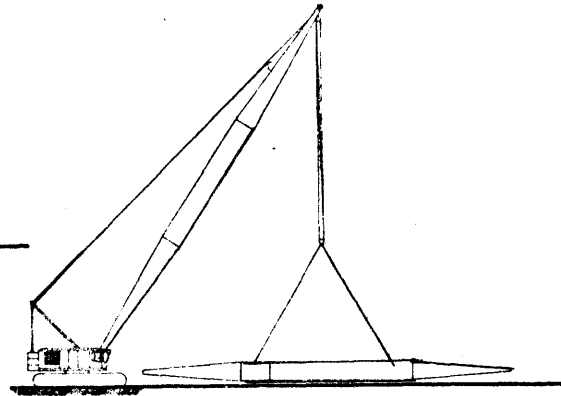
NOTE: In accordance with varying material situations, and the company's policy of constant product improvement, these specifications are subject to change without notice and without incurring responsibility to units previously sold.

GUY DERRICK ASSEMBLY & TRAVEL

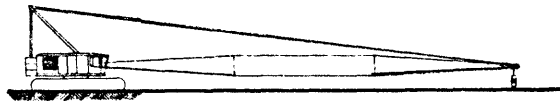
1. Assemble mast on ground. With another crane, pin mast into upper boom foot.



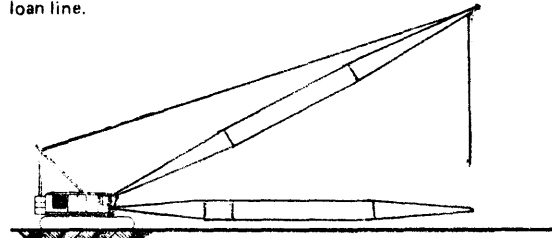
2. Reeve mast suspension line and connect suspension pendants.



3. Raise mast parallel to ground.
NOTE: Due to industry standards governing rope safety factors on the pendants, 260 and 270 feet of mast must be assisted to a height of 100 feet above the ground. Reeve boom suspension line.

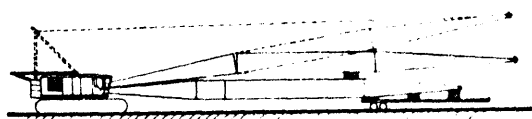


6. Lower mast to 30° and connect boom suspension. Raise mast to 45°. Hoist boom parallel to ground and reeve loan line.



4. Attach guy lines to guy cap.
5. Using mast as boom (as with another crane) assemble boom on ground and pin into lower boom foot.

7. Raise mast to vertical position and attach guy lines to anchors. Tension guy lines and raise boom to a working position. Readjust guys until guy cap is plumbed above crane turntable.



TO TRAVEL WITHOUT HEIGHT RESTRICTION

1. Equally support boom outer section on flat bed trailer.
2. Lower mast to 45° angle.
3. Tie guy lines to mast inner section and travel.

TO TRAVEL WITH HEIGHT RESTRICTIONS

1. Equally support boom outer section on flat bed trailer.
2. Lower mast until the stop bracket on the boom inner section contact the mast inner section.
3. Tie the mast inner section to the boom inner section.
4. Remove the two top splice pins between the mast inner section and the first center section.
5. Place blocking on top of boom at a sufficient height to allow the mast to lie parallel with the boom.
6. Lower mast* to blocking, retract A-frame and travel.

*If mast is longer than 180', another crane must assist mast down because mast suspension pendants will contact lacing.

Load handling capability of the AMERICAN Model 11250 crawler crane is tremendously increased (up to 10 times) with the addition of the Guy Derrick attachment. The reason for this great increase is because with the guy lines attached this machine is impossible to tip and, therefore, all ratings are based on strength. Boom and jib combinations to 490 feet are available.

COMBINATION BOOM: Basic Guy Derrick boom is 130 feet long and consists of 35 foot inner, 10 and 50 foot centers, and 35 foot outer with six offset sheaves in the boom point. All sections of this pin connected 94 inch cross section boom are constructed of tubular T-1 steel chords and tubular-lattice. Maximum boom length is 350 feet. The 1100 Series SKY HORSE attachment also utilizes this same boom. Boom sections are interchangeable with conventional lift crane boom.

GUY DERRICK MAST: The basic 94 inch cross section mast consists of a 50 foot inner, 50 foot center and 50 foot mast tip. All sections are pin connected and constructed of tubular T-1 steel chords and tubular lattice. The inner section, which is mounted in the upper boom foot, contains guide sheaves for the load and whip line. The mast tip has three boom suspension line sheaves and an anti-friction bearing guy cap. Mast height may be extended to 270 feet with the addition of 10, 20 and 50 foot center sections. These same mast components are also used for the SKY HORSE attachment.

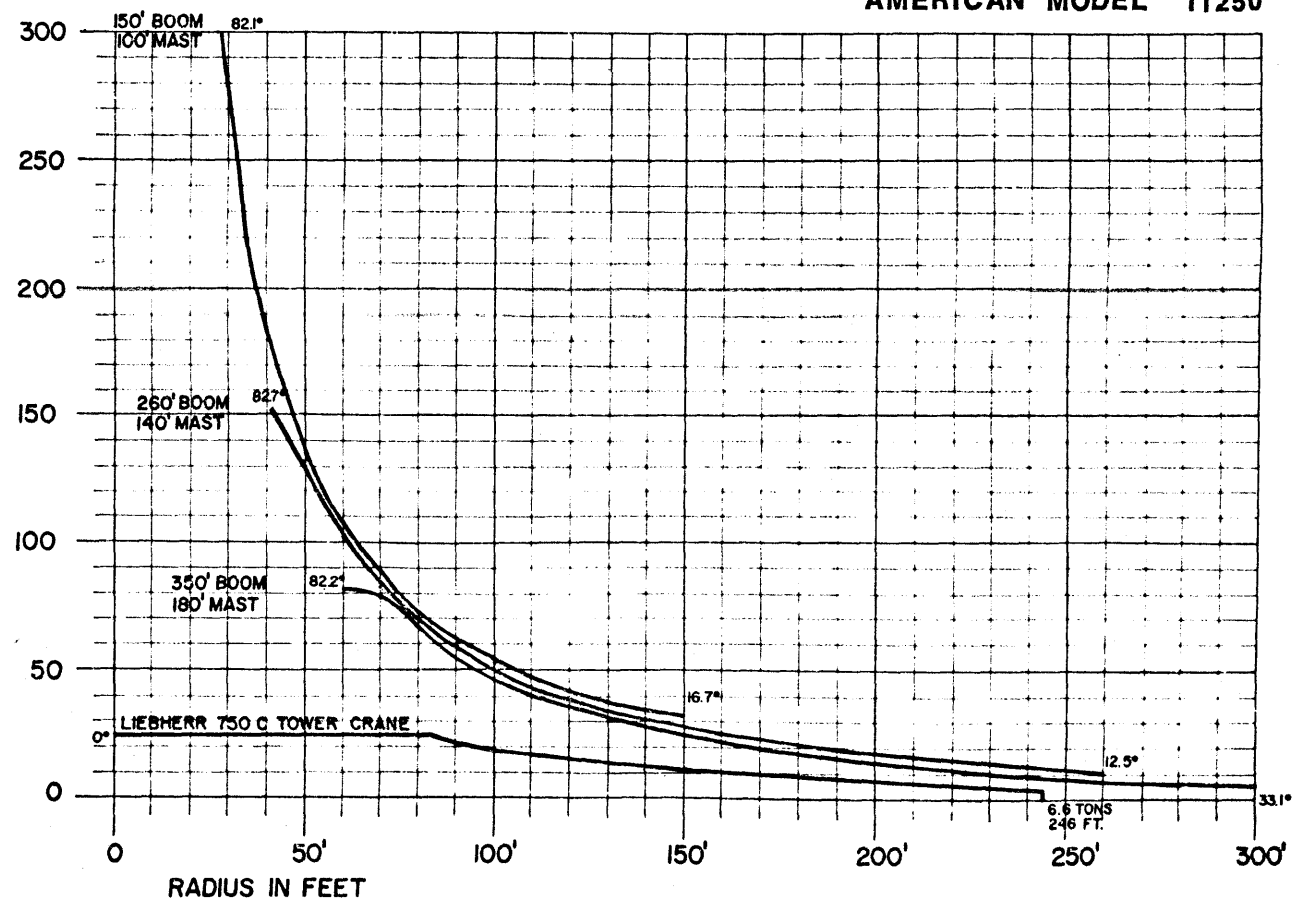
SKY HORSE RATINGS

21 BOOM LENGTHS FROM 150ft. to 350ft. ARE AVAILABLE
 LENGTHS 150ft., 260ft., and 350 ft. ARE COMPARED WITH A TOWER CRANE

LOAD CAPACITY

IN TONS Lifted over side using 110,800 lbs. counterweights
 and trailing 200,000 lbs. counterweight.

AMERICAN MODEL 11250

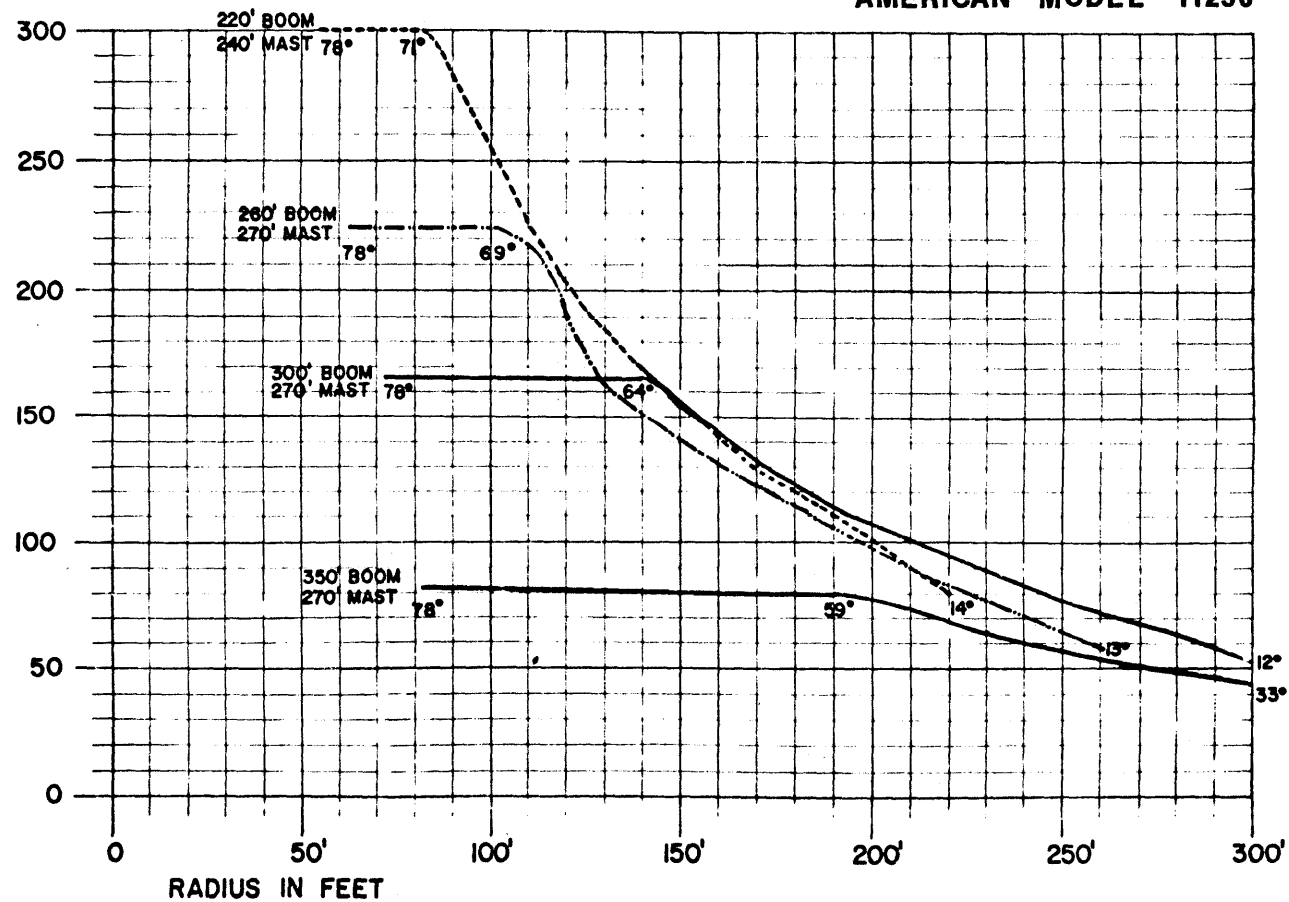


GUY DERRICK RATINGS

23 BOOM LENGTHS FROM 130 ft. to 350 ft. ARE AVAILABLE
LENGTHS 220 ft., 260 ft., 300 ft. and 350 ft. ARE SHOWN

LOAD
IN TONS

AMERICAN MODEL 11250



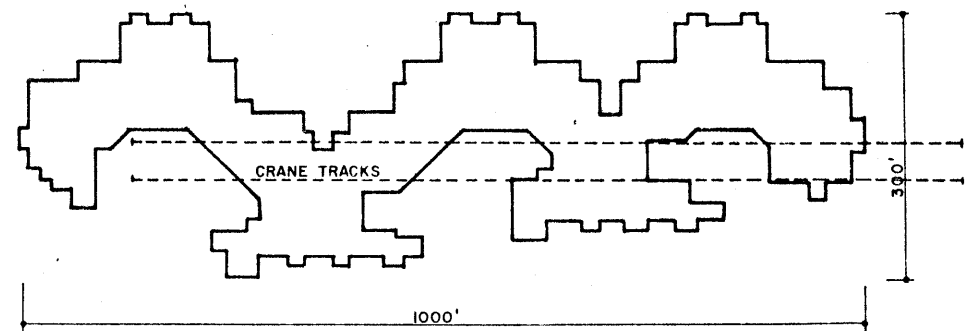
EXAMPLES: Crane Applications

Describing the construction of Habitat, architect Moshe Safdie writes:

"The big Dominion Bridge Crane had a capacity of a hundred and fifty tons at the base, but only seventy tons at a distance of a hundred and twenty feet from its edge. We didn't know the exact distance of the boxes when we ordered it. This first box to be lifted weighed eighty tons and was one hundred and eighty feet out--too big for the crane at that distance. We suggested getting another, smaller crane, then we would put the two cranes opposite each other and the box in the middle, connect them both to the cross bar on which the box would be placed. This would give each crane the proportion of the load it could carry, i.e., it would be proportional to the distance from the end of the cross bar to the box.

The contractor insisted that this procedure was absolutely impossible. They delayed the job two weeks arguing that it couldn't be done. Under pressure from Churchill they at last brought in the other crane, put in the cross bar, and lifted the box. The whole thing was done in front of the press in forty-five minutes without one problem. The procedure became so simple that

any time the extra crane was required--for about five percent of the boxes--they just brought it in without question." [23]



PLAN OF HABITAT WITH CRANE TRACKS

Source "CONTEMPORARY CONCRETE STRUCTURES" by A. Komendant, 1972 p.535

The crane used to erect the WEYMOUTHPORT project for ECHO GROUP, Inc. was a 125-ton American crawler crane.

This system was described on page 98.

The crane was used as a standard crane up to the fourth story construction, but for higher levels was equipped with a Sky-Horse attachment, a water-filled counter-balancing unit which increased the capacity of the crane 150%.

The erecting firm (Curtis Steel of Norwood) had a special jig designed which fit all the various sized modules for rapid hoisting. With a 200 ft. main boom and a 60 ft. jib, the Sky Horse could swing a 32 ton load out 85 feet. As the buildings neared completion, the main boom was increased to 260 ft.

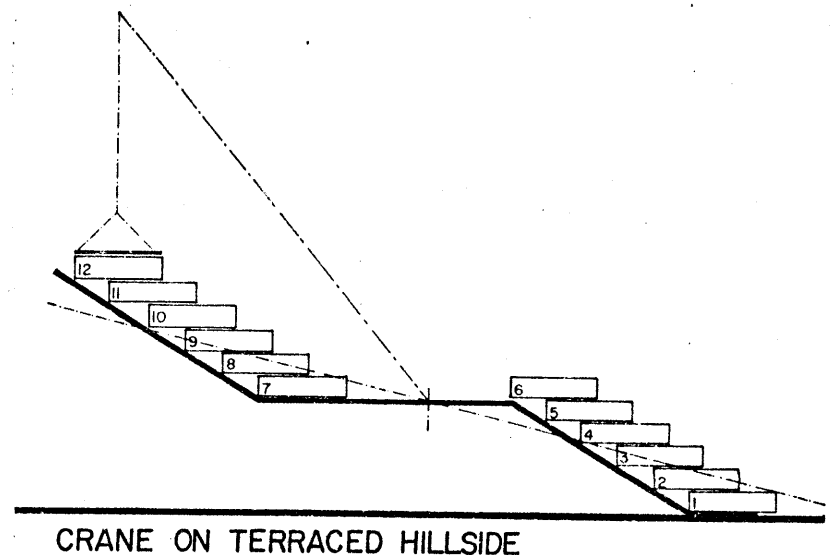
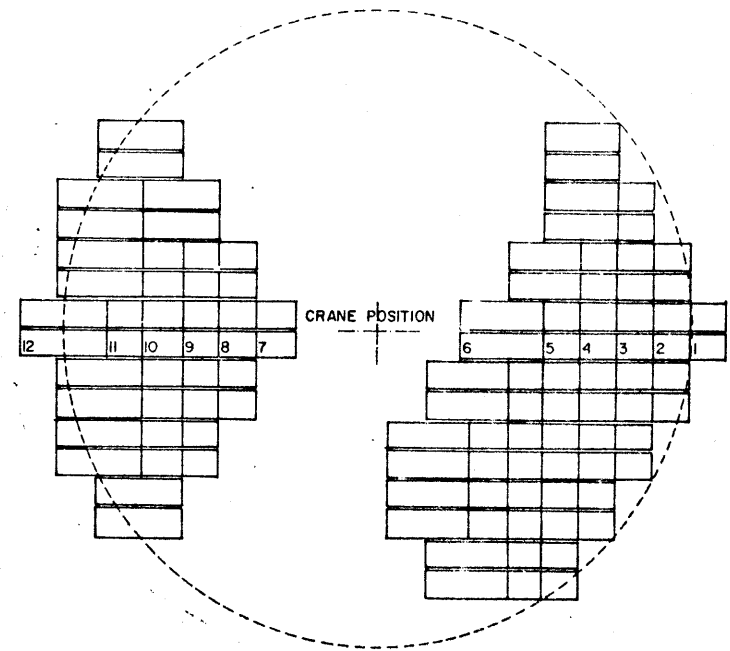
The crane used to erect the "Palacio del Rio" for H.B. Zachry Company of San Antonio, Texas was a 350 h.p. crane equipped with a special 36 foot diameter ring base and a 270 ft. boom, as described on page 94.

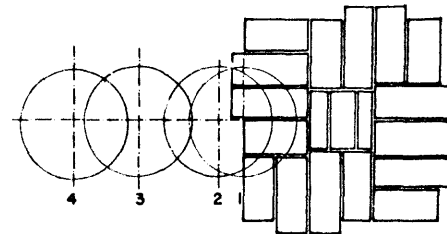
A pair of 60-ton cranes is used in Finland to place each 40-ton AUSA concrete box-unit. (See Page 93) One of the problems encountered is the necessity to keep all four lifting points level to avoid torsional strains.

A tower crane on a terraced hillside, or a road along the hill, could reach about 115 ft. with a 33-ton box-unit or about 140 ft. with the lightest box-unit of 25-tons, to a hook-height of 262 ft.

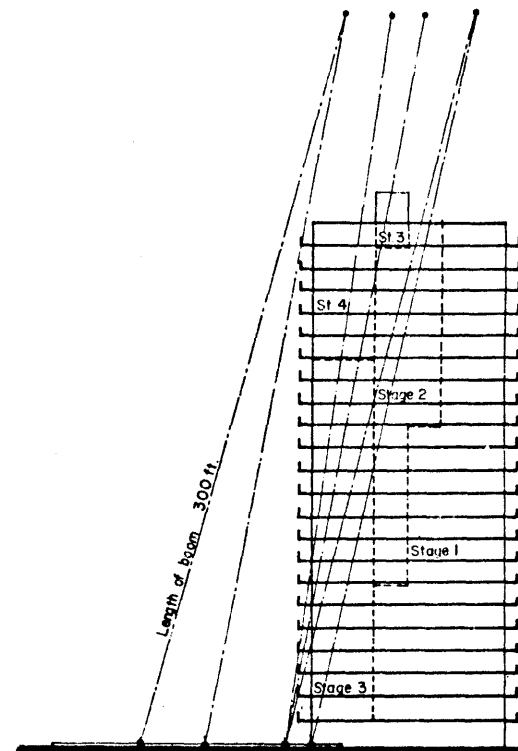
Area for unloading and handling box-units would have to be provided. The diagram is a conservative estimate of the reach of the tower crane. Buildings up to 20 stories or more could be easily erected.

Crawler cranes could also be used. These cranes can maneuver a slope of about 13 degrees without being dismantled. Crawler cranes do not have the ability to maintain lifting capacity at great distances: as shown on page 128, lifting capacity drops sharply as radius increases.





ERECTION SEQUENCE FOR HIGH-RISE BUILDING
PLAN OF TOWER AND FOUR CRANE POSITIONS



ERECTION SEQUENCE FOR TOWER
Source: PROF. EDUARDO CATALANO

PROJECT ORGANIZATION

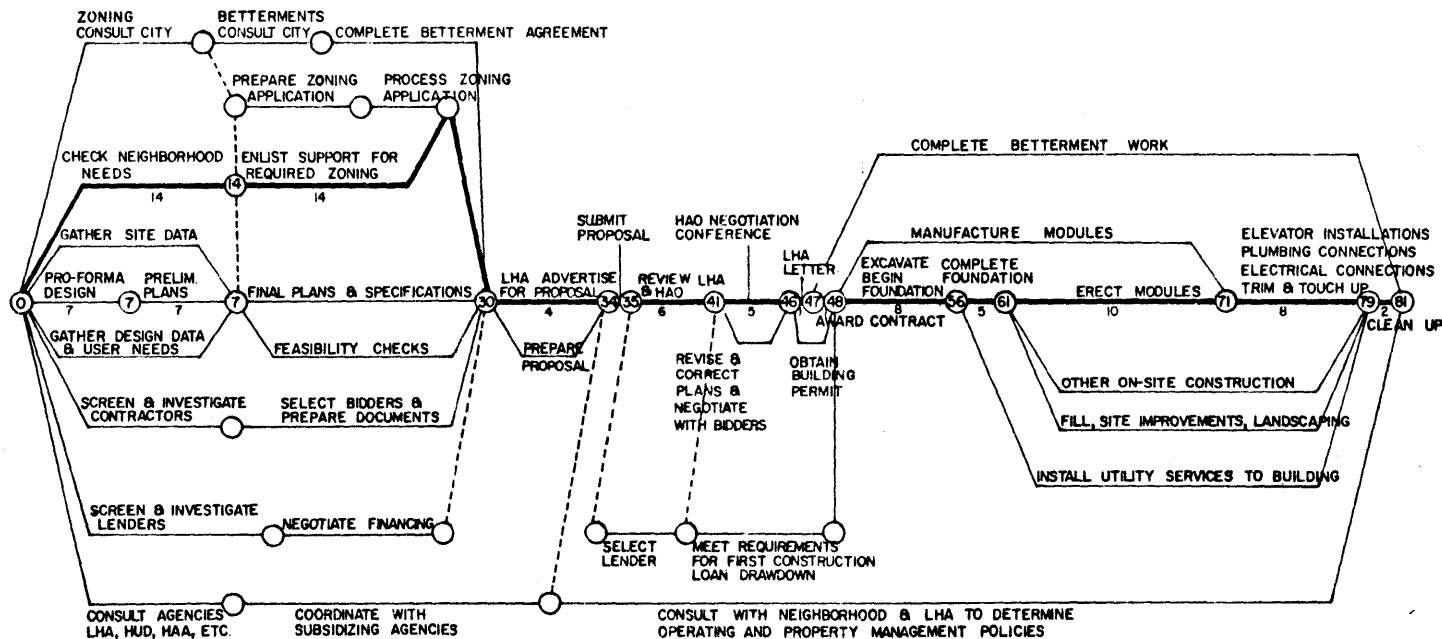
The site erection rate is determined by the factory casting rate, for although there is probably a buffer stock of elements in the storage yard (as flat panels) sufficient for two or three weeks' supply, this will soon be used up if the elements are being erected faster than they are being produced. Moreover, should an element need to be replaced or repaired, a buffer stock is needed to prevent a hold-up in scheduled erection.

Although boxes take longer to erect than panels, there is an overall savings in erection time since the box comprises six-panel-elements or sides. This point is often overlooked when it is asserted that such units are awkward to erect.

Fifty units a day is to be regarded as the maximum attainable. The erection time varies between 1-3 man-hours per square meter (square feet) of habitable floor space and will constitute 15-25% of the total amount of labor entailed by the prefabricated units. [26]

CRITICAL PATH SCHEDULE

Box-Unit Housing Project



Adapted with permission of the M.I.T. PRESS
from "Industrialized Housing Feasibility Study"
by A. Herrey and W. Little, Cambridge, Mass. 1971

SOURCES FOR CHAPTER V

- #1 A. Herrey and W. Litle
INDUSTRIALIZED HOUSING FEASIBILITY STUDY
M.I.T. Press, Cambridge, Mass. 1971
- #2 MHMA 37th ANNUAL REPORT TO THE MEMBERSHIP
March 22, 1973 Mobile Homes Manufacturers Ass.
- #3 SYSTEMS BUILDING NEWS magazine
- #4 David Eacret
THE ECONOMICS OF INDUSTRIALIZED HOUSING
U. Michigan Thesis (Rotch TH1000 E116)
- #5 Kenneth Campbell, Editor
PROFITS AND THE FACTORY-BUILT HOUSE: 1972 UPDATE
Audit Investment Research, Inc.
- #6 PROFESSIONAL BUILDER magazine
Cahners Publishing Co., Chicago, Ill.
- #7 MANUFACTURED HOUSING: AN OUTLINE
- #8 ENGINEERING NEWS RECORD magazine
McGraw-Hill Publishers, Albany, N.Y.
- #9 Kenneth Campbell, Editor
1970: PROFITS AND THE INDUSTRIALIZED HOUSE
- #10 INTERNATIONAL SYMPOSIUM ON BOX-UNIT CONSTRUCTION
CIB Proceedings #26, 1973 Balatonfured, Hungary
- #11 Moshe Safdie, BEYOND HABITAT, M.I.T. Press
- #12 H. B. Zachry Co., San Antonio, Texas, Brochure
- #13 Telephone Interview: Mass. Dept. Public Works
- #14 ECHO GROUP, INC. Brochure
Fort Lauderdale, Florida
- #15 T. Koncz
PRECAST CONCRETE CONSTRUCTION
VOLUME III. LARGE PANELS
Bauverlag GmbH, Wiesbaden, Germany

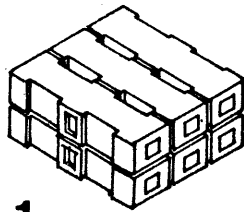
FOOTNOTES

- 1 Source # 1 p. 104
- 2 Source # 1 p. 105
- 3 Source # 1 p. 97
- 4 Source # 2 p. 11
- 5 Source # 1 p. 96
- 6 Source # 3 p. 13
September, 1974
- 7 Source #13
- 8 Source # 4
- 9 Source #13
- 10 Source # 5 p. 38
- 11 Source # 6 p. 137
October, 1973
- 12 Source #12
- 13
- 14 Source # 9 p. 38
- 15 Source # 1 p. 102
- 16 Source # 6 p. 113
- 17 Source # 1 p. 108
- 18 Source # 1 pp. 38
- 19 Source # 8 p. 23
July 19, 1973
- 20 Source # 1 p. 106
- 21 Source #10 p. 6
Paper II-6 Variel
- 22 Source #10 p. 4,5
Paper II-6 Variel
- 23 Source #11 p.
- 24 Source #14
- 25 Source #15
- 26 Ibid.

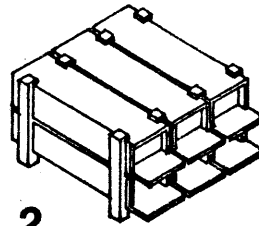
VI. Review of Box-Unit Structures Using Concrete

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2. Some Concrete Box-Unit Types.....	142
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4. Hybrid Systems: Box-Units with On-Site Concrete Infill.....	146
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a. Assembly Methods for individual boxes.....	151
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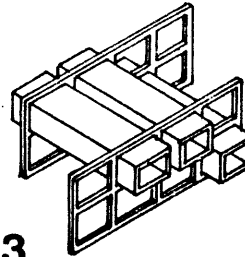
CONCRETE STACKING SYSTEMS



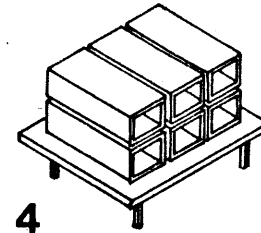
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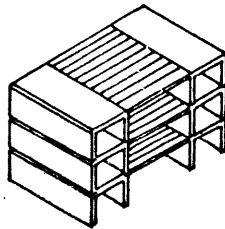
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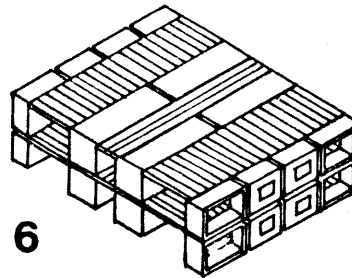
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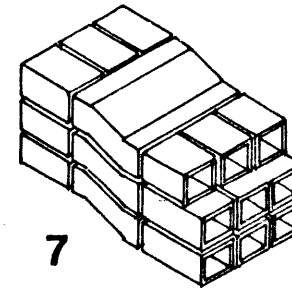
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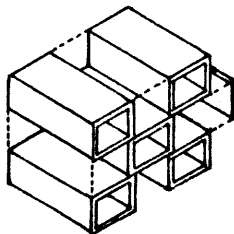
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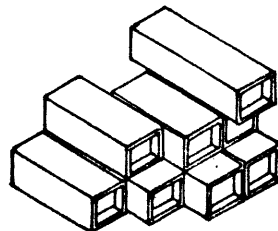
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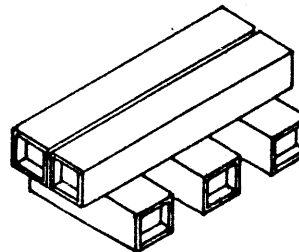
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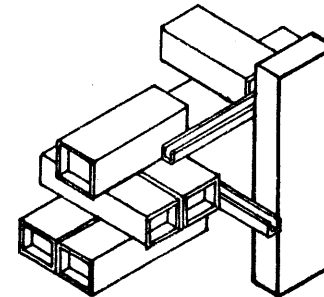
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9



10



11

1 RUSSIAN STACKING SYSTEM

The central corridor is included in the long box. A 3" gap between boxes allows space for welding. A variation would be to allow larger gaps for poured-in-place concrete. [1]

2 HABSYSTEM by F.D. Rich, Jr.

Units are thin-shelled box-beams spanning the depth of the building. Columns are cast on site. Plenum space surrounds each box to provide air circulation for heating. Suited best for single-loaded buildings.[2]

3 "BOTTLE-RACK" SYSTEM

Idea used for Marseilles Apartment Block (Unité d'habitation) in 1950 by Le Corbusier where light-weight units were placed in a reinforced concrete frame.[3]

4 PLATFORM SYSTEM

Lightweight boxes can be supported on precast, cast-in-place, or lift-slab platforms. [4]

5 BOXES WITH SPANNING PLANKS

Boxes can be 3-or 4-sided. Idea proposed by Ill. Inst. of Technology and Cornell. Boxes contain kitchens and baths, planks allow larger living-rooms. [5]

6 ECHO SYSTEM

Interior planks span between exterior plates. Lightweight 'core' kitchens and bathrooms are separate. [6]

7 MID-SECTION SYSTEM

Center section can contain kitchens and baths with split-level stairs. Option to have mid-section in two separate sections.

8 SHELLEY SYSTEM

The "Shelley" System allows box-units to be stacked alternately.[8]

9 OFFSET SYSTEM

The "Offset System" proposed in this paper coordinates structure and mechanical system to be staggered at regular intervals.

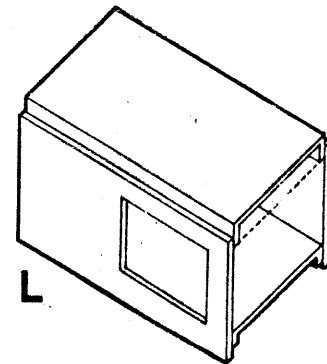
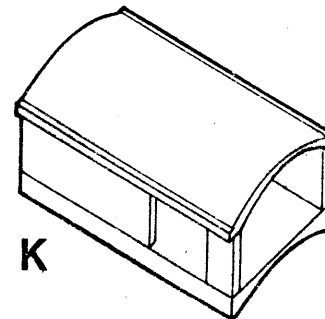
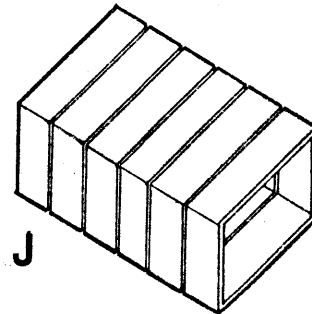
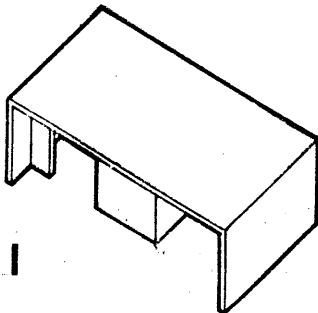
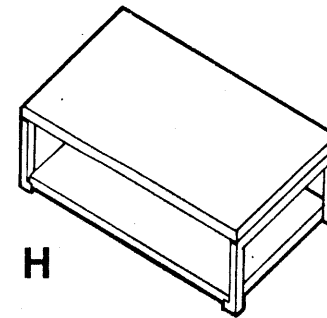
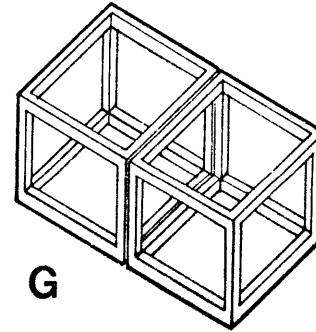
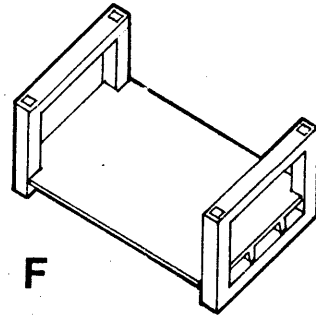
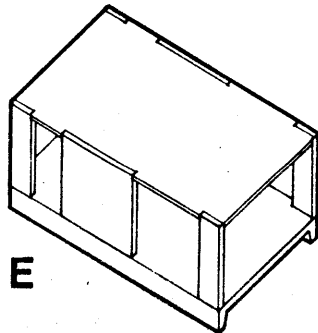
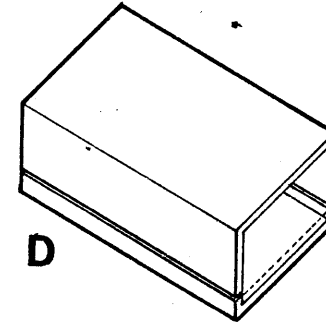
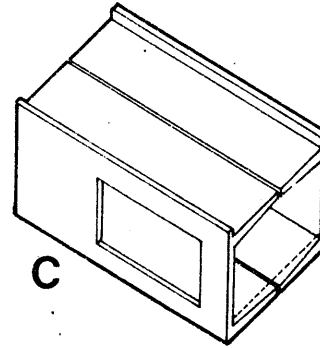
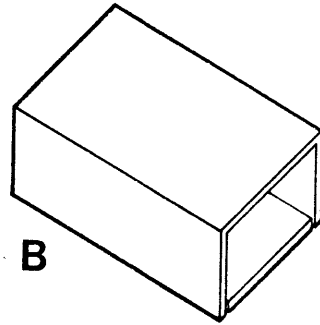
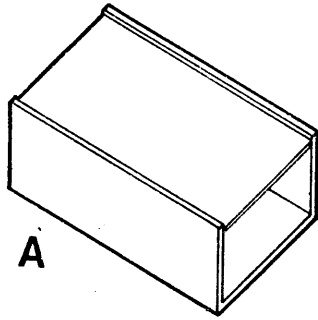
10 SPANNING BOXES

Supports are arranged in square bays so boxes can be rotated 90 degrees. This system is usually proposed for steel construction. [9]

11 COMPOSITE SPANNING BOXES

Boxes with custom design for each building application can assume almost any configuration. This type was used for HABITAT '67.[10]

SOME CONCRETE BOX-UNIT TYPES

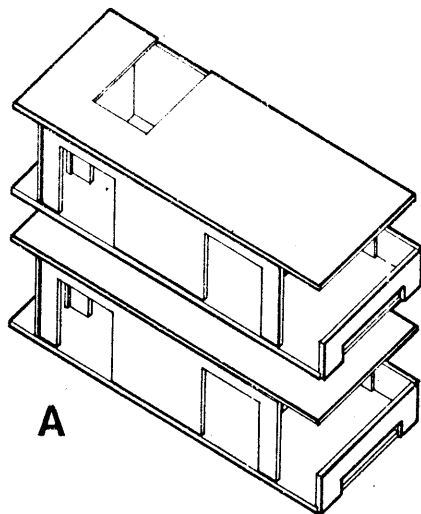


- A** Box cast in two pieces: with separate ceiling. The inner form may be removed after 4 hours of air-curing because the form does not carry the top slab as in other types. [11]
- B** Box cast in two pieces: floor separate. The bottom slab is connected by special screw devices or by welding plates.
- C** Box cast of two side sections: this method is favored by Kommendant [12].
1. Sidewalls can be varied in thickness; buttresses can be easily provided.
 2. Window & door openings can be installed in a horizontal casting position.
 3. The joint at mid-point is least subjected to stresses, regardless of loading conditions.
 4. Transport and handling easier.
- If the sides are tapered to enable easy removal from forms, some type of fill or separate floor is needed. Also, the 10'6" overall height shown by Kommendant is excessive for housing.
- D** Bottom slab with upturned edges: This method is used with 5" walls to allow bending double-reinforcing into walls by the H.B. Zachry Co. Eric Chen, MIT graduate student, proposed the location of joint at mid-point in the walls. [13]
- E** Box with supports at ends; the deep floor carries loads

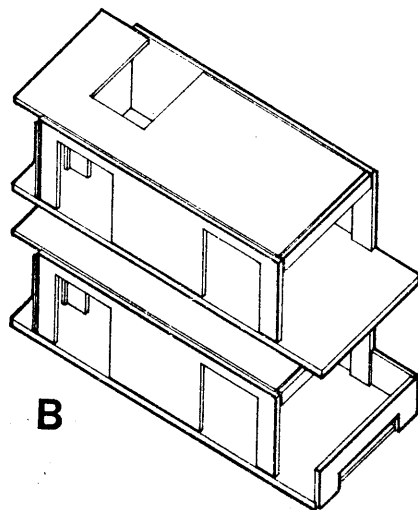
- F** Exterior wall or frame is load-bearing. The floor can be ribbed to carry loads length-wise.
- G** Framed Box. This principle is used by CONBOX of Denmark [15] and by the Uchida Lab in Japan [16]. Usually steel construction; requires infill.
- H** The VARIEL System. The box is supported on four corners but can only attain height of 3 floors. Advantage is ease of transport and adaptability to non-housing uses. [17]
- I** STRESSED STRUCTURES, INC. System. Interior walls are cast together with special cements; note that the top of the ceiling becomes the floor for the unit above.
- J** RING-MODULES proposed by many, including Van Vliet in Holland [18], GO-DB Arquitectos, Assoc. in Spain [19] Building Block Modules in USA [20].
- K** FLEX-BAU SYSTEM by Elementwerk der Gebr. Brun, AG in Lausanne, Switzerland. [21]
- L** Overlapping System: similar sections for floor and roof arranged so placement is facilitated. Suspended ceiling is necessary to cover edge.

Box-units assembled from panels are shown on the following pages.

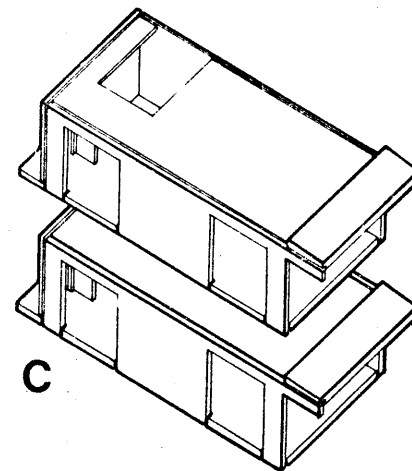
BOX-UNITS ASSEMBLED FROM PANELS



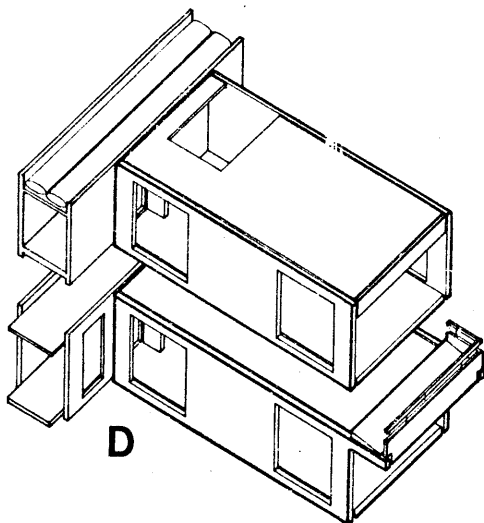
A



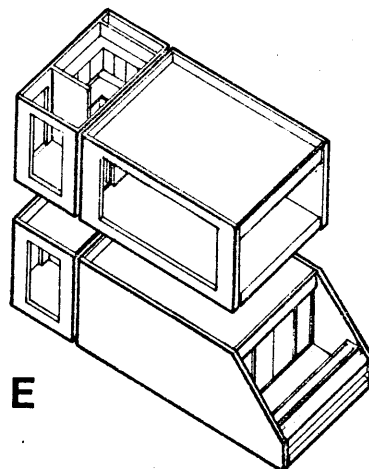
B



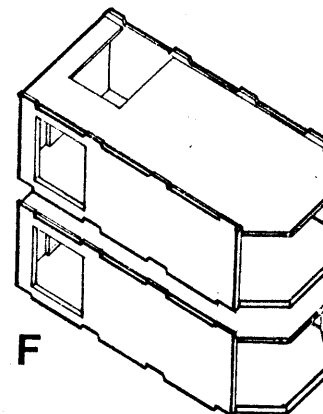
C



D



E



F

- A** Walls between floor and top slab. Easily placed and assembled. Walls do not contribute to cantilevering action of floor slab. Vertical loads pass through 3 connections at each section between boxes.
- B** Same as "A" but ceiling recessed and beam is applied to stabilized boxes at front and ends. Vertical loads pass through 2 connections at the section.
- C** Floors and ceiling recessed. Floors notched at openings. Vertical loads pass through one connection at the section. Note the extension of the beam carries the balcony slab. This slab, separate from both the ceiling and floor slab, affords an effective thermal break in cold climates.
- D** Same as 'C' except the corridors are separate loadbearing forms up to 60 ft. long depending on the building type. This system allows the corridor to be pre-finished in the factory. The corridor could be a strong design element since it can cantilever out from clusters of box-units.

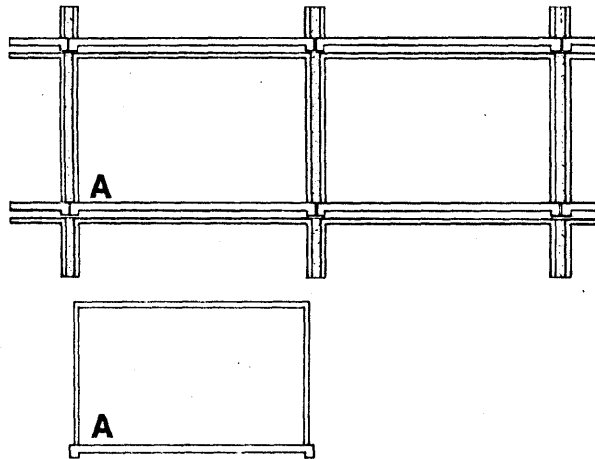
- E** Similar to 'D' but with kitchens and bathrooms as separate 3-D elements cast in concrete. One advantage is the larger clear span living room by turning the 14'-0" shipping dimension to the side. Interior cores can be combined with stairs to create split-level apartments.

The large openings could apply to examples and F but for A, B, and C, the resulting wall section would be more likely to break or be damaged.

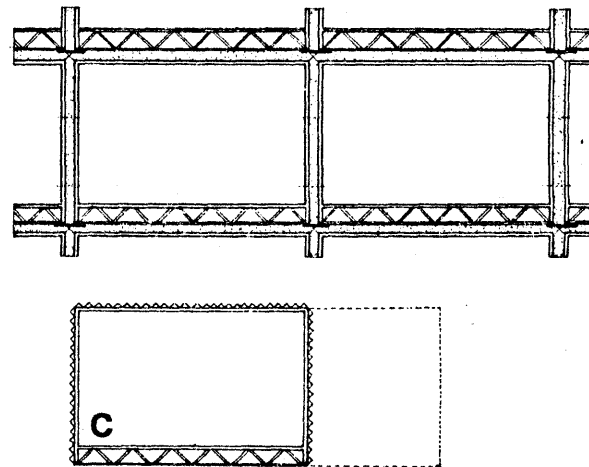
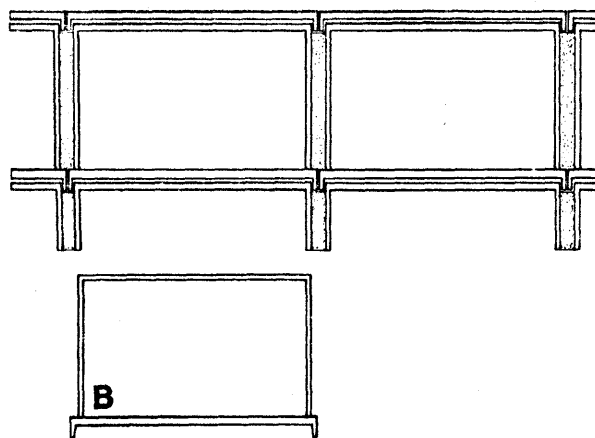
- F** Notches in the wall section provide shear keys and help increase the depth of section under openings. Use of a two-way reinforced floor slab opens possibilities of creating interesting building facades.

Note: For examples of other types of box-units and systems, including suspension structures and vertical bathroom cores, the reader is also referred to theses by Graduate A.S. Students in the Department of Architecture at M.I.T.

HYBRID SYSTEMS: Box-Units with On-site Concrete Infill



- A. Box-unit which bears upon poured-in-place concrete fill between walls up to the top of the ceiling level.
- B. Similar to A except fill level is lower to enable ceiling to nest inside floor. Difficulty is keeping fill at desired level for all units.
- C. Box with floor-truss: may vary in depth and type of materials used.



The 'Hybrid' systems shown on the opposite page feature finished lightweight box-units with poured-in-place concrete poured between the units to form structural supports where needed. These systems have the following advantages:

1. The lighter box-units are easier to transport and erect than concrete boxes.
2. Like other box-units, prefinishing, electrical and mechanical work, etc. can be done in the factory--but manufacturing techniques of the mobile home industry could be utilized.*
3. The on-site concrete allows for structural continuity, and only as much concrete as is needed for support or fireproofing need be used.
4. In some cases, as in example C, access space for ducts, etc. can be provided in the floor.

* Professor Zalewski, in addition to suggesting the basic structural types from which examples A, B, and C have been adapted, has also envisioned the use of modified mobile homes as the lightweight box-units types.

Some of the considerations involved:

1. Protection of the box-units during handling and transport is necessary. The box may not be as rigid as a concrete box, but it might resist handling and torsional stresses with use of stressed skin materials (ie, plywood sheathing, etc.) and stresses caused by dead load would be much less.
2. Walls must be designed to withstand the hydrostatic pressure of the poured-in-place concrete. Walls can not leak: otherwise the pre-finished box-unit will become soiled.
3. There is little or no saving in the width of wall required. Since the minimum bearing width for each unit would be about 3", the infill would need to be 6" minimum. To that must be added the dimension of the lightweight wall.
4. Temporary bracing could be used during fabrication, transport, and while pouring the infill. For structures similar to example C, the ceiling would require strengthening or bracing.
5. This type of construction works well in vertically aligned structures. When offsets, cantilevers, zig-zags, changes of levels, etc. are desired, many 'special' design conditions arise as to make their use questionable. Also, the end-units require special formwork.

TWO EXISTING SYSTEMS WITH OPPOSITE APPROACHES

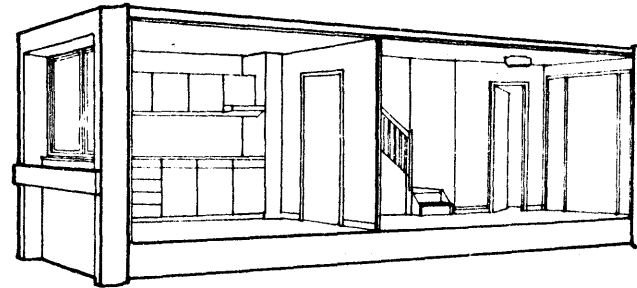
The VARIEL SYSTEM and the RUSSIAN CAP TYPE SYSTEM represent two European examples with opposite approaches.

The VARIEL SYSTEM has end supports only, and is designed for buildings up to 3 levels. Its use is not limited to housing. Production in 1972 was 75% schools, 10% offices, 10% residential and 5% miscellaneous.* Estimated production for 1974 was 12,000 modules including plants in France, Belgium, Germany, Holland, Sweden, and South Africa. The ELCON A.G. is studying the possibility of plants in Israel, Czechoslovakia, and Chile.

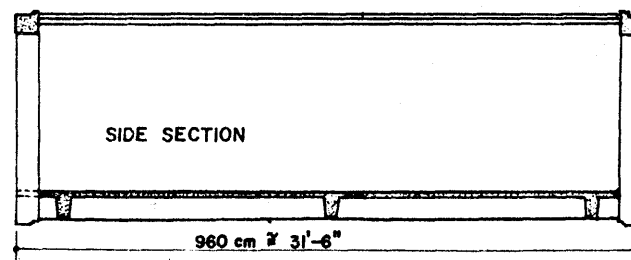
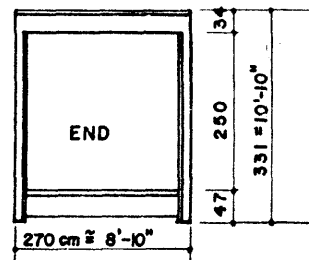
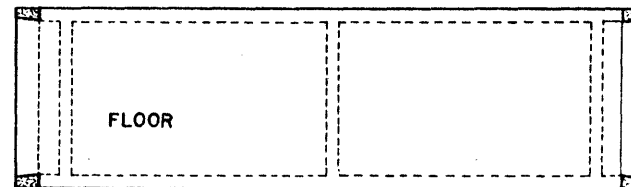
The RUSSIAN CAP TYPE SYSTEM represents one current concrete box-unit type with adaptation for spanning panels. In contrast to the Variel System, the Russian unit is definitely designed for housing and openings are very limited.

*Engineering News Record Magazine
July 19, 1973, p. 23

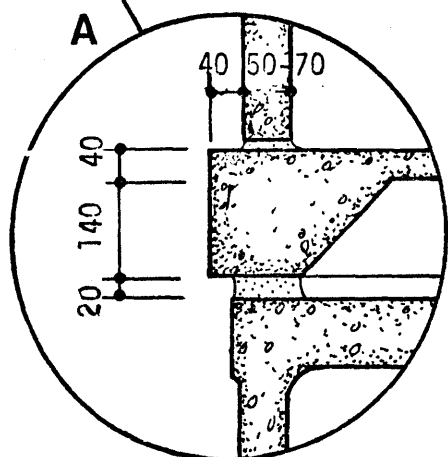
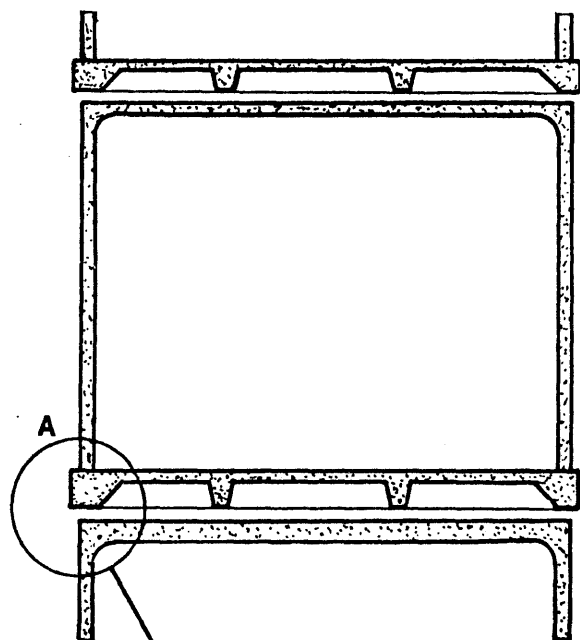
1. VARIEL System



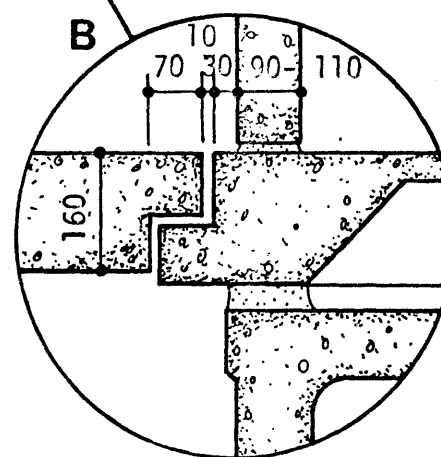
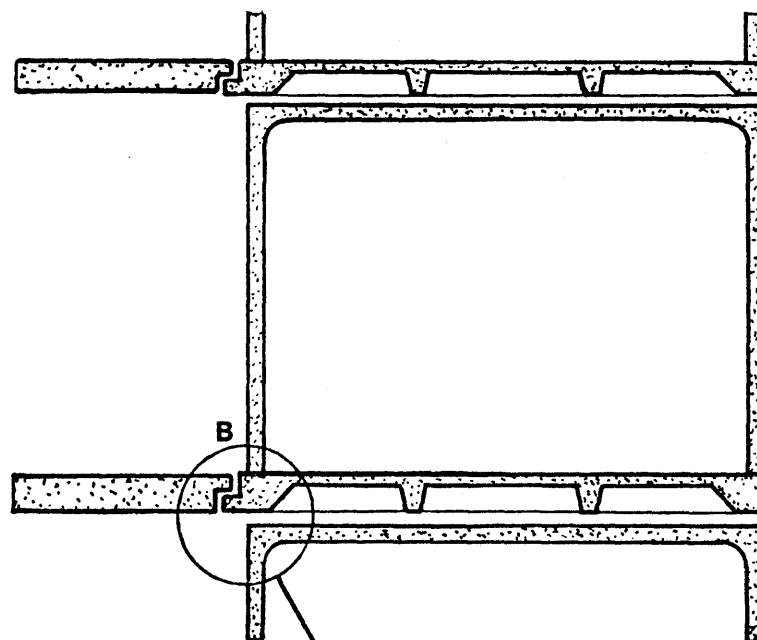
Source: International Symposium on Box-Unit Construction
CIB W19 S56 1973 Paper II-6 H.Grüssl



2. RUSSIAN BEARING WALL System "CAP TYPE"



dimensions in millimeters



Source: CIB Proceedings #26 Paper II-14
E.L. Viesman and N.B. Levontin
Institute TSNIIEP zhilishcha "Cap Type"

ASPECTS OF BOX-UNIT DESIGN

Obviously, the design of the box-unit depends on complex relationships of function, modular/dimensional relationships derived from intended use and available products, provisions for mechanical equipment and access, relationships to other components such as elevators, corridors, and stairs, methods of manufacture and assembly, and constraints of transportation and erection. Of course, in the final analysis, the product must be one which is desirable and profitable.

In a narrower sense, the structural design can be discussed with regard to

1. The individual box-unit,
and
2. The final building assembly.

As illustrated on page 140, "Concrete Stacking Systems", it is clear that the two aspects are interdependent: the desired final building assembly determines the structural design of individual box-units.

Some methods of producing individual box-units have already been discussed in CHAPTER IV. MATERIALS AND METHODS.

Unfortunately, not enough material has been found or published which gives detailed technical information on existing systems, especially with regard to connections and casting machinery, with the exception of the sources referred to. Note that the complicated forms of HABITAT required equally complicated and expensive detailing as shown by Komendant.

Other ideas concerning detailing and connections can be found from the thesis work of former M.I.T. graduate students in the Advanced Studies program of Architecture under the supervision of Prof. Catalano and/or Prof. Zalewski. Other systems and assembly types are also presented.

Four of the methods used to assemble individual box-units are shown on the opposite page.

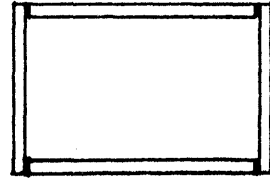
Type 1 relates to BOX-UNITS ASSEMBLED FROM PANELS: all examples on page 144 except 'A' and 'B'.

Type 2 refers to the same types as 1.

Type 3 relates to example B on page 142 and the 'Cap Type' on page 149.

Type 4 refers to type D shown on page 142.

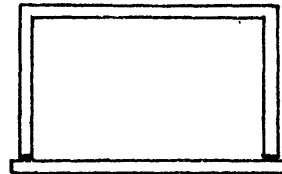
SOME WAYS TO ASSEMBLE INDIVIDUAL BOX-UNITS



1. Four panels are welded so that transfer of apartment floor loads are transferred by shear to the bearing walls. Major vertical loads from units above are taken directly through the walls.



2. Four panels are assembled so that floor and ceiling are compressed between the walls. Cables or threaded rods are tightened after application of special epoxy. This method may require later leveling of the floor.



3. Two separately cast pieces are joined together with dowels so that the floor supports the walls. The upper "U" can be formed by many methods. The floor should extend beyond the walls to facilitate forming.



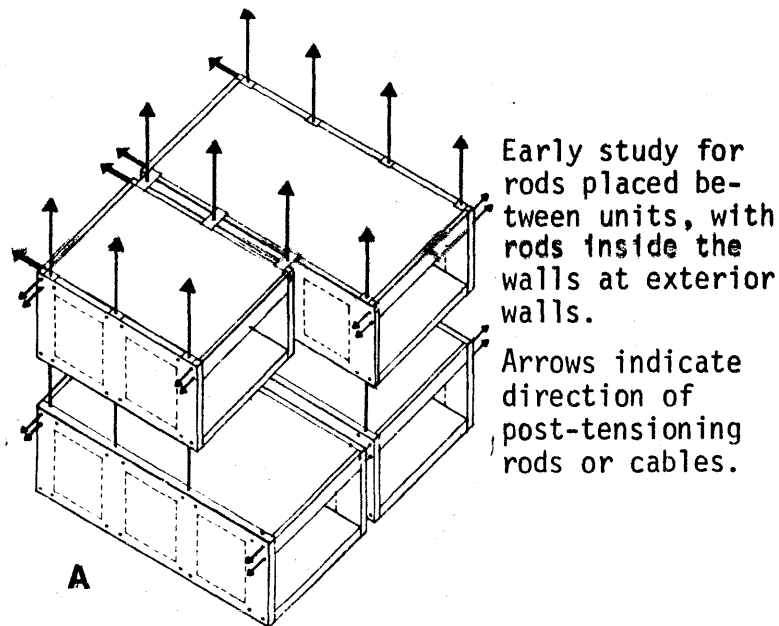
4. Two components are joined together by bending reinforcing steel upwards and casting the upper shell on top. Walls should be 5" minimum for this method.

POST-TENSIONING

Post-tensioning seemed the ideal way to tie box-units together vertically and horizontally--especially because it is often advocated.

However, some of the problems which were encountered led to attempts to find simpler methods.

First: is post-tensioning necessary? Tying the units together can be achieved by other means, such as the methods on page 179 or 181. The weight of the building and depth/height ratio can be shown to resist earthquake forces.

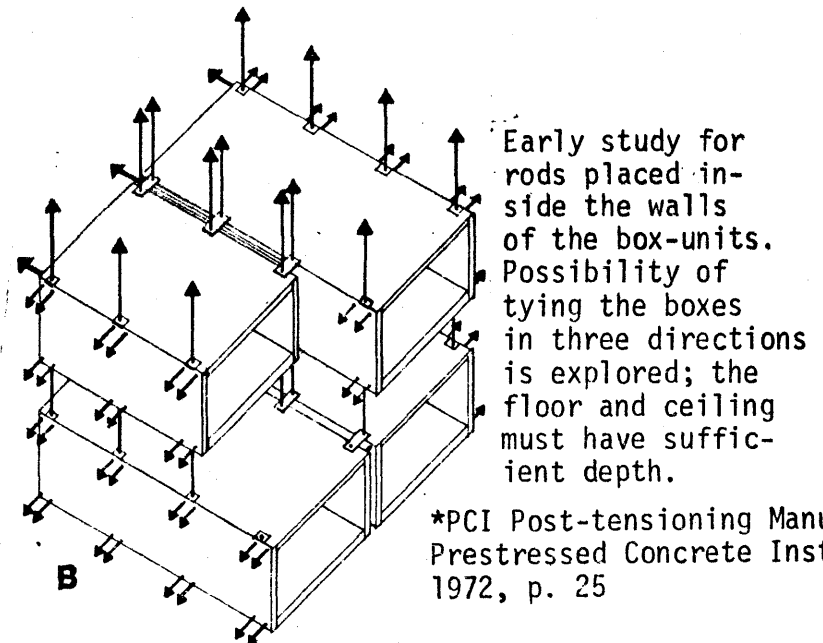


Early study for rods placed between units, with rods inside the walls at exterior walls.

Arrows indicate direction of post-tensioning rods or cables.

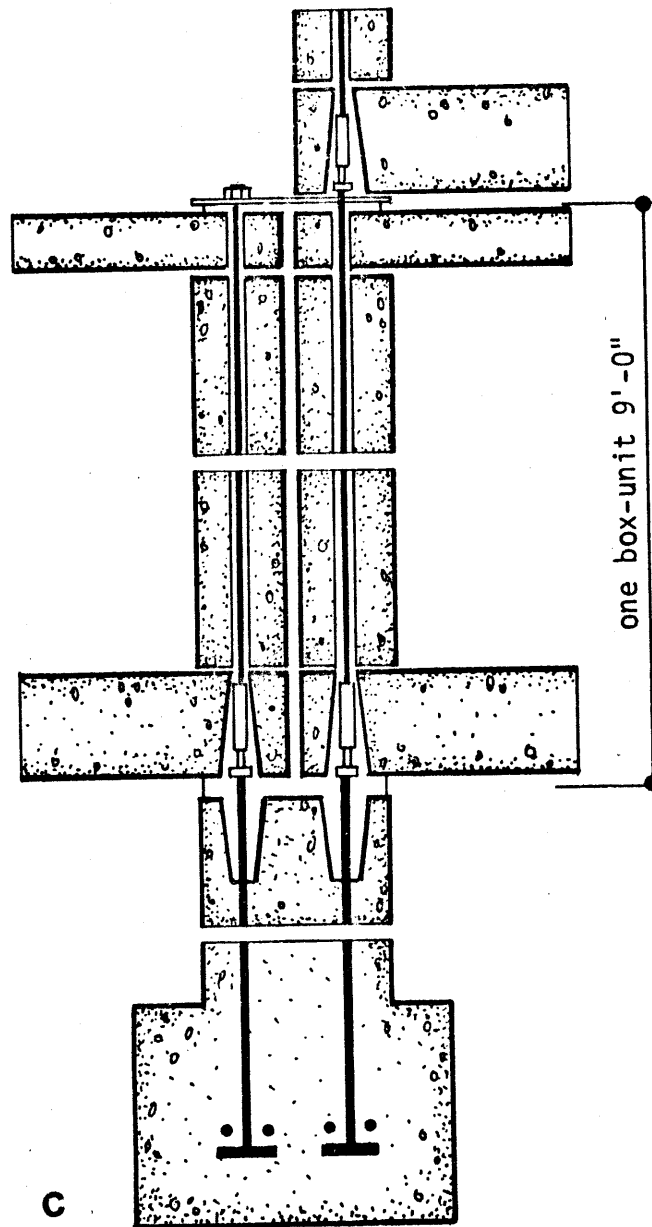
Problems encountered were:

1. Difficulty of placing the box-units accurately. If the rods are to be within the walls, the box-units must either be threaded over the rods or special rods inserted from above and rotated to secure the connection below.
2. Depth of walls required. In order to make a continuous connection, deep pockets or recesses for access must be provided. Also, the device for anchorage has considerable dimensions. The walls of Habitat ranged from 5" to 12"--but this meant a box 17.5 ft. x 38.5 x 10 ft. weighing 80 to 95 tons.*



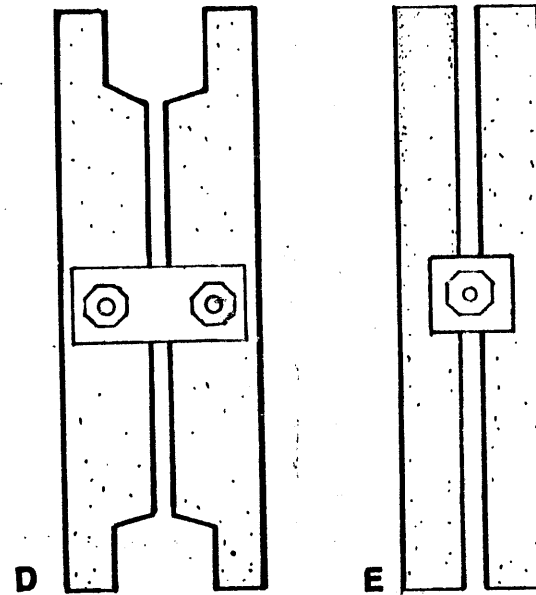
Early study for rods placed inside the walls of the box-units. Possibility of tying the boxes in three directions is explored; the floor and ceiling must have sufficient depth.

*PCI Post-tensioning Manual
Prestressed Concrete Institute
1972, p. 25



An early study attempting to adapt post-tensioning details from panel construction is shown at C. Note that there is no way for Box 4 to be secured. Note relative size of connection required, and weakening of the floor section at the connection.

The rod placed between walls enables thinner walls to be used; it seems the only feasible approach to post-tensioning if the rod protrudes one level above the unit being placed.



VII. Proposed Offset System: Structure

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Isometric diagram of typical box units. The diagram shows two units: a larger one in the background and a smaller one in the foreground. Dimensions are provided in feet and inches:

- Top unit (background): 13' 9" (width), 13' 0" (depth), 10' 10" (depth), 9' 0" (height).
- Bottom unit (foreground): 28' 2" (width), 6' 6" (depth), 2' 2" (height).
- Staircase: 6' 6" (width), 2' 2" (height).

Typical Box Units



SYSTEM CHARACTERISTICS

The proposed OFFSET SYSTEM is characterized by its assembly from large precast concrete panels, and by the location of supports at 8'-8" intervals which allow it to be 'offset'.

The box-unit is as completely finished as possible in the factory, including mechanical and electrical equipment and end walls and windows.

Because the walls, ceiling, and floor are separate panels, various combinations of panel types can be selected to suit varying design conditions. For example, a coffered floor could serve as a mat in poor soil conditions, while a two-way reinforced floor slab could serve where shaped balconies are desired. Different types of wall and floor combinations and the resulting weights of box-units are given on the following pages. The right combination will depend on desired effect and total costs involved, and including box weight.

However, the proposed system is based on a modular increment or grid of 1'-1" (13"). Since many large openings are desired in the side walls, the wall is designed so maximum openings are 6'-6", leaving "columns" of 2'-2" for load-bearing sections.

The maximum height of openings at doors is 7'-0", so there is always a "beam" at the top of the panel; Likewise, there is always a bottom strip on the wall panel where the floor slab connection is made.

Depending on conditions, the "beam", the ceiling slab, and the floor slab can cantilever. In some cases, the "beam" could cantilever to carry a separate corridor or balcony slab for the box-unit above.

Although the concrete panels could be manufactured to any dimension, the planning module used has been shown to adjust to most apartment and building types.

Two main box-widths are proposed:
10'-10" and 13'-0".

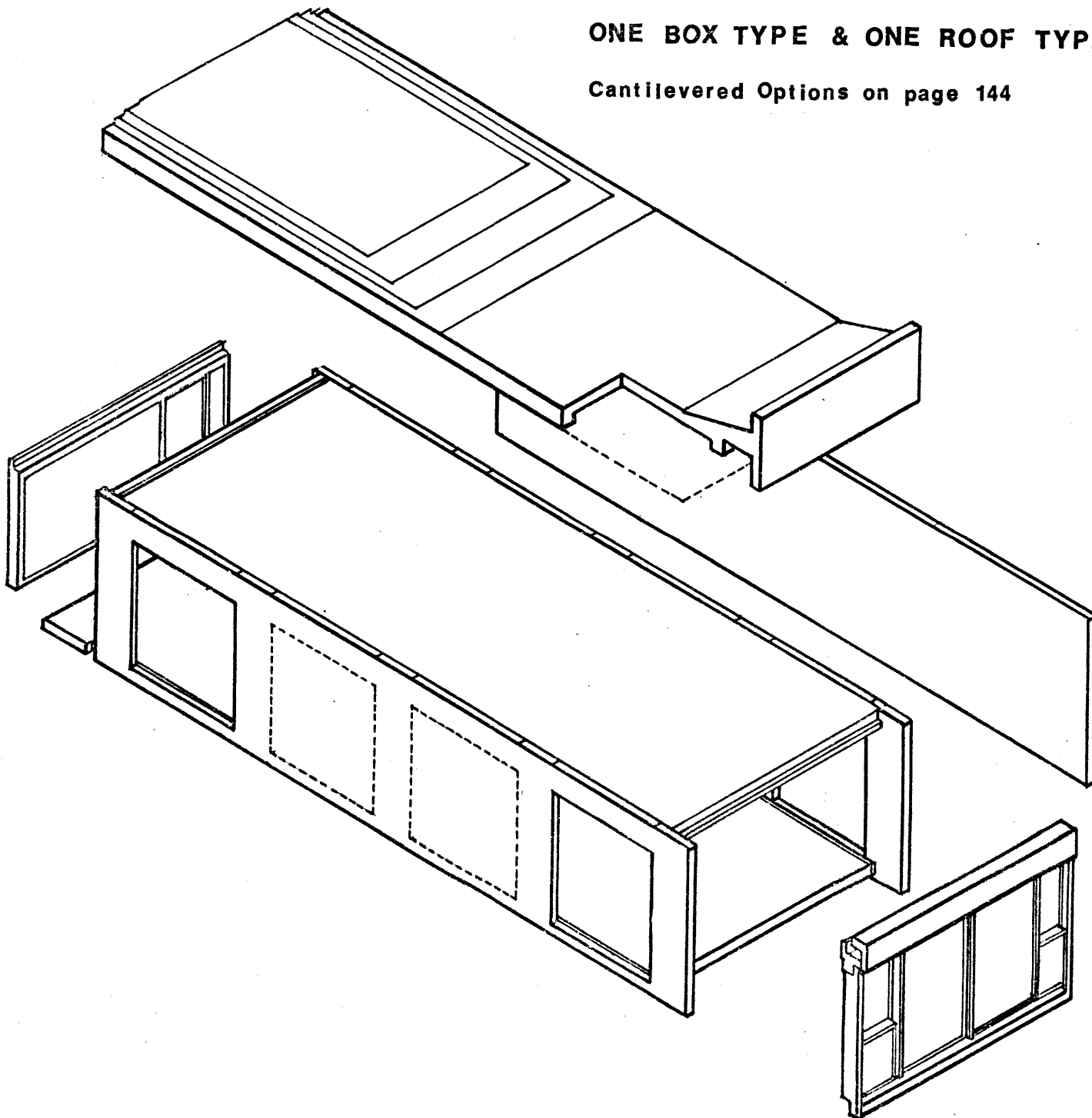
Box lengths are:

19'-6"
28'-2"
36'-10"
45'-6"
54'-2"

Note that when two 6" ribbed walls and one 1" joint are used, the resulting 13" corresponds to the modular grid.

ONE BOX TYPE & ONE ROOF TYPE

Cantilevered Options on page 144

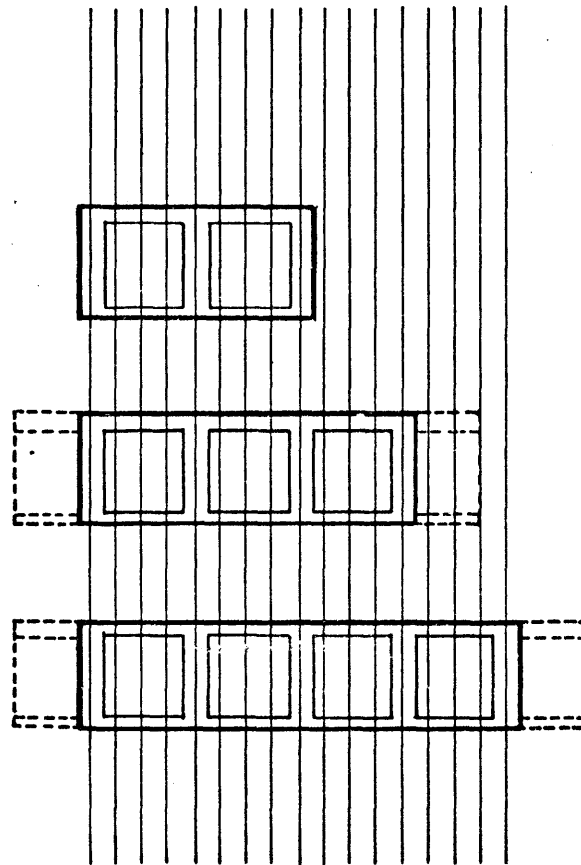


2'-2" MODULE

9'-0" x 19'-6"

28'-2"

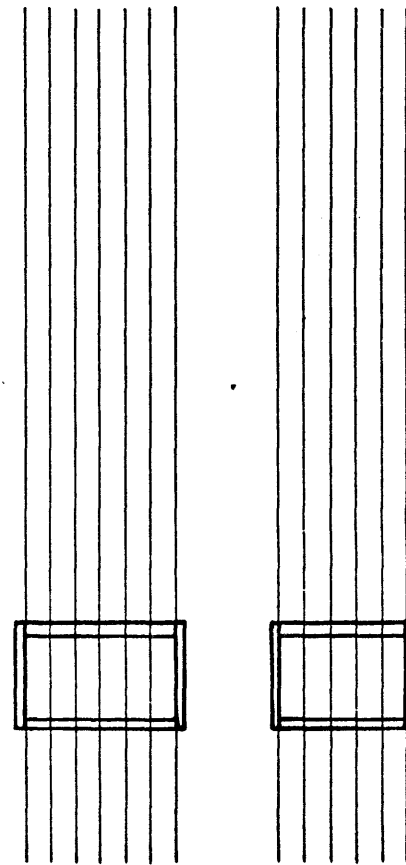
36'-10"



Side Walls

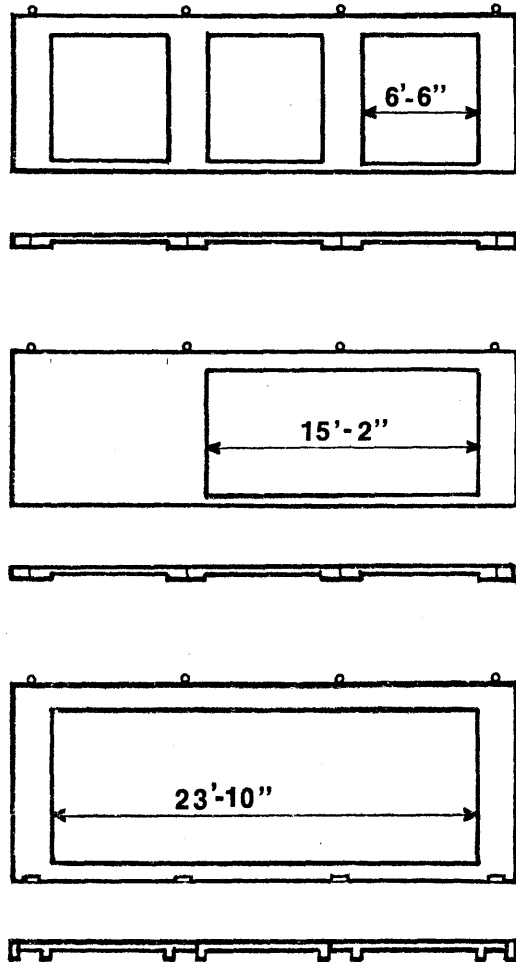
13'-0"

10'-10"



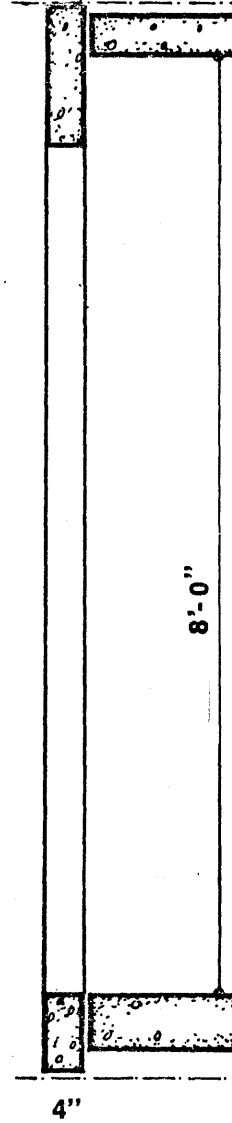
End Walls

WALLS

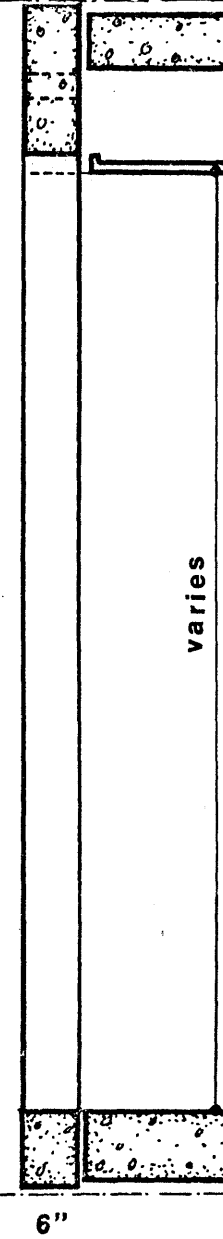


OPENING SIZES

9'-0" RESIDENTIAL

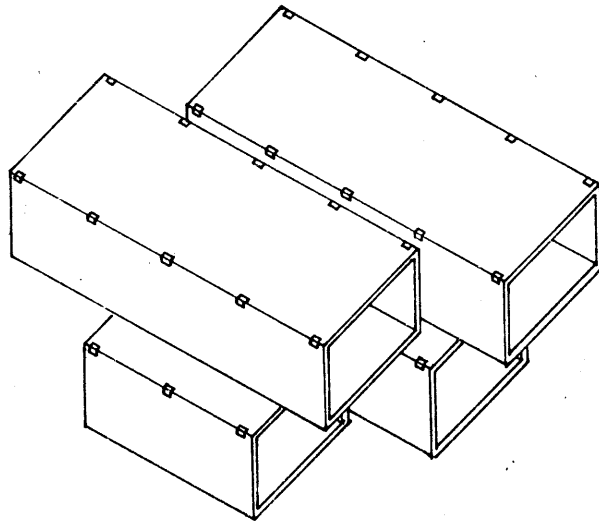


Variable OTHER USES



WALL SECTIONS

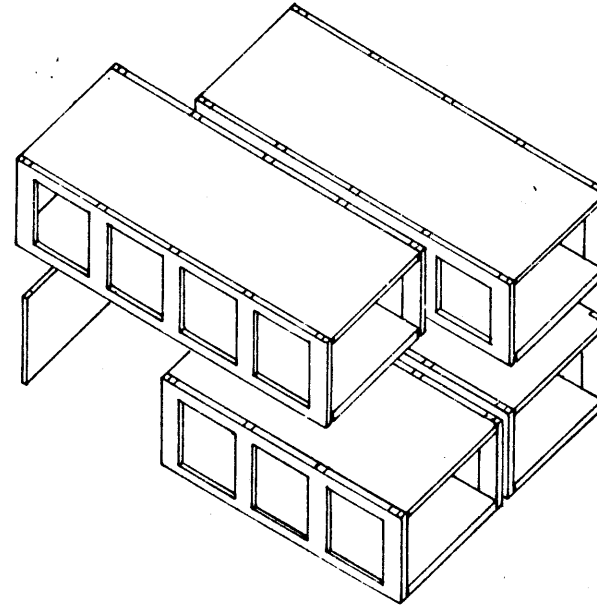
A. No side openings



- A.** When there are no openings in the side of the box-unit, a box-beam structure results. This is an economical structure for hotels, dormitories, hospital rooms, and other units where each box contains the complete living area.

The walls can cantilever at greater distances than those containing many openings.

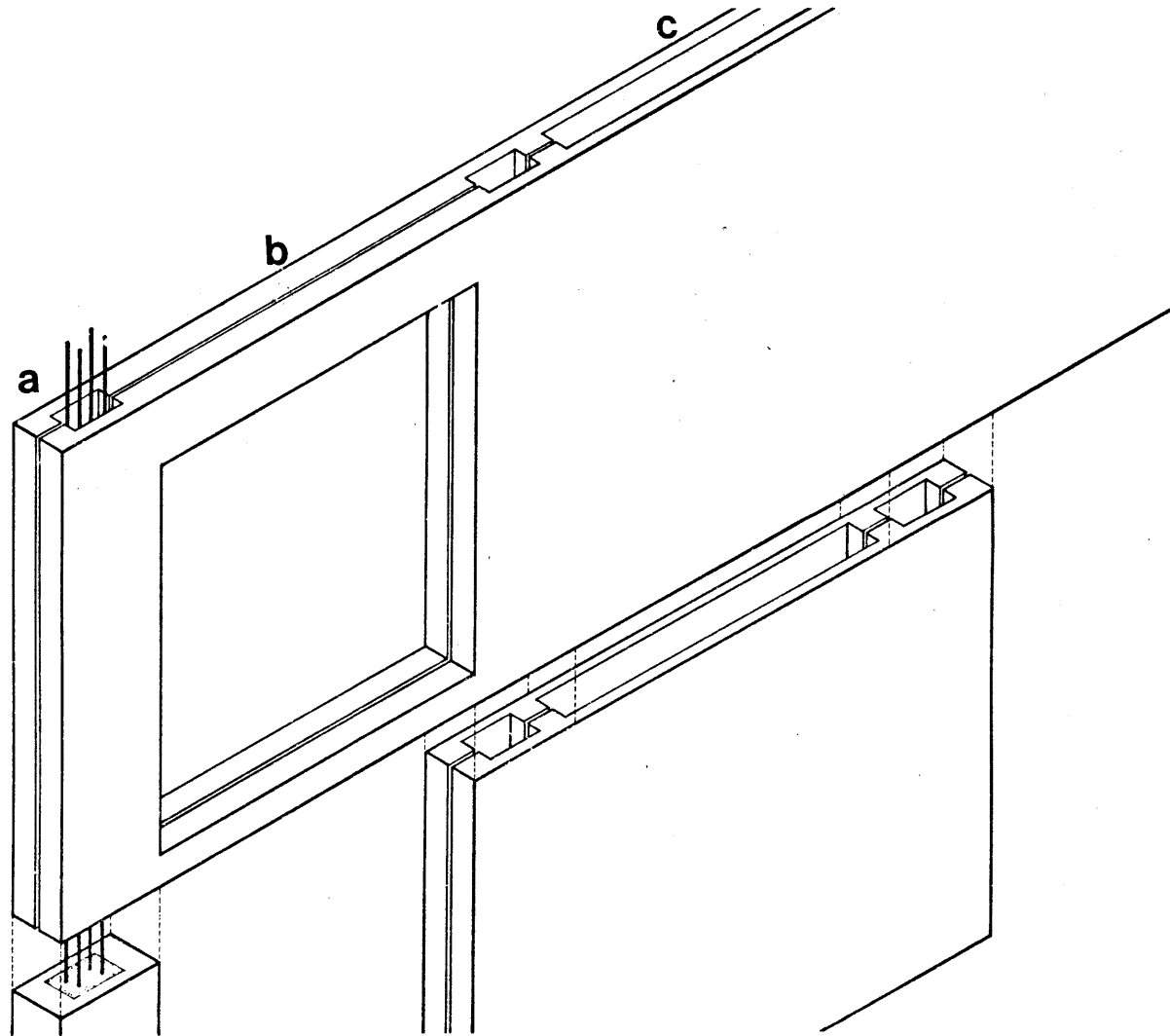
B. Maximum number of openings



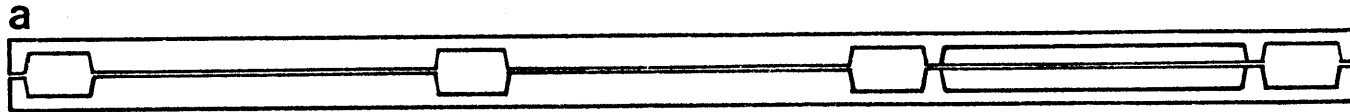
- B.** The side walls are shown with the maximum number of openings at regular intervals--as would be used for living rooms with two exposures.

When the upper 'beam' is reinforced to carry the extra loads, a center 'column' could be removed to create an opening of 15'-2". By increasing depth of the 'beam' (i.e., increasing the floor-to-floor height of the box-unit for special applications) and using three bays, an opening 23'-10" would result.

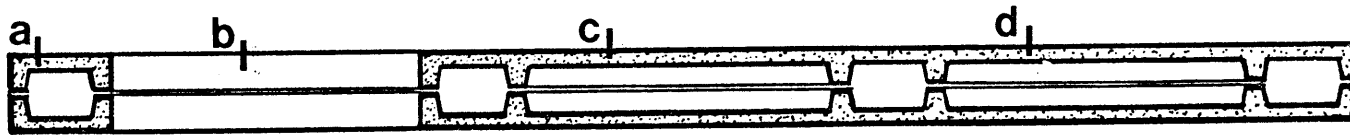
ON-SITE CONNECTIONS



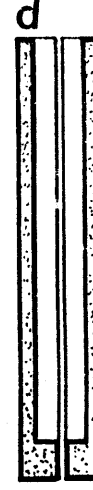
WALL SECTIONS



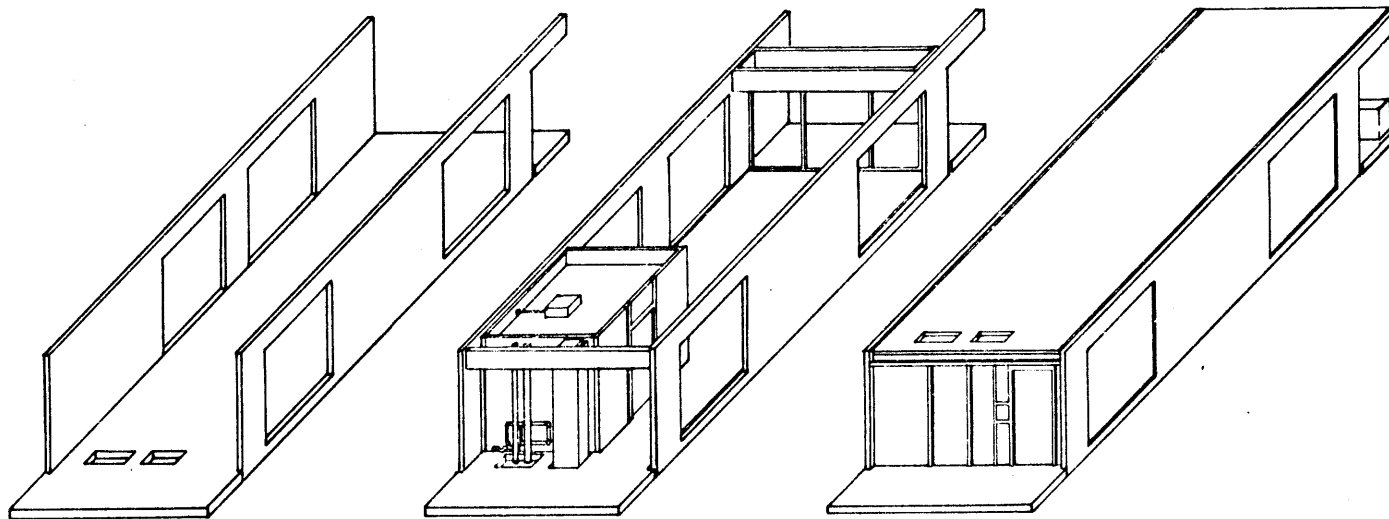
Top View



Section



FACTORY ASSEMBLY SEQUENCE



Floor Unit is placed.

Wall panels brought by overhead tracks and aligned and braced.

Walls welded at supports.

Lateral beams attached and welded or doweled.

Bathroom core or components placed.

HVAC equipment installed.

Front wall placed.

Electrical raceways installed.

Trim attached where necessary.

Ceiling lowered and attached by welding.

Patch and grout.

Seal joints at junctions of components and walls or ceilings.

Attach light fixtures and plates.




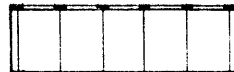

Install finish flooring.

Place on-site connections and equipment inside unit.

Place corridor wall with access panel open for on-site work.

Install protective panels and covering. Inspect and label.

BOX WEIGHTS

ALL CALCULATIONS FOR BOXES 13'-0" = 4 m WIDE WITH 4"=10 cm HOLLOW CORE CEILING FLOOR TO FLOOR HEIGHT 9'-0" = 274 cm WEIGHTS GIVEN IN TONS. 1 TON=2000 lbs. = 907.2 kilograms						
		6" FLOORS	5" RIBBED WALLS 4" HOLLOW CORE WALLS 4" SOLID WALLS	BATHROOMS KITCHENS	4" CEILING (36.8 psf)	
 19'-6"	SLAB BAND	4.7	6.4 5.0 6.4	3.0	4.7	18.8 17.4 18.8
	HOLLOW CORE	5.5	6.4 5.0 6.4	3.0	4.7	19.6 18.2 19.6
	SOLID SLAB	7.0	6.4 5.0 6.4	3.0	4.7	21.1 19.7 21.1
 28'-2"	SB	6.7	9.2 7.0 9.0	3.0	6.7	25.6 23.4 25.6
	HC	7.9	9.2 7.0 9.0	3.0	6.7	26.8 24.6 26.6
	SS	10.1	9.2 7.0 9.0	3.0	6.7	29.0 26.8 28.8
 36'-10"	SB	8.8	12.0 9.8 11.8	3.0	8.8	32.6 30.4 32.4
	HC	10.3	12.0 9.8 11.8	3.0	8.8	34.1 31.9 33.9
	SS	13.2	12.0 9.8 11.8	3.0	8.8	37.0 34.8 36.8
 45'-6"	SB	10.9	14.8 11.4 15.0	3.0	10.9	39.6 36.2 39.2
	HC	12.7	14.8 11.4 15.0	3.0	10.9	41.4 38.0 41.6
	SS	16.3	14.8 11.4 15.0	3.0	10.9	45.0 41.6 45.2
 54'-2"	SB	13.0	17.6 13.6 18.0	3.0	12.9	46.5 42.5 46.9
	HC	15.1	17.6 13.6 18.0	3.0	12.9	48.6 44.6 49.0
	SS	19.4	17.6 13.6 18.0	3.0	12.9	52.9 48.9 53.3

NOTE : Approximate average weight is 1 ton per linear foot for 13'-0" wide box units

The typical box-unit is assembled from large panels. Flat walls and ceiling are more economical to manufacture, especially if battery molds are to be used. The floor slab could be a slab-band as shown to reduce weight, or a 6" two-way reinforced flat slab when a cantilevered floor is desired to form corridors or balconies.

The following tables give the basic wall types and their respective weights:

1. Infill panels and/or pour with cellular concrete.
2. Ribs
3. Hollow Core
4. Solid Slab

The 4" Hollow-core wall is lightest at 28 psf, including a solid strip which acts as a column.

Basic floor types are:

1. Slab-band
2. Hollow core
3. Solid Slab

Note that these floors span the short dimension of the unit, i.e., 13'-0". The lightest floor suitable which is shown is the slab-band floor with 3" concrete between 6" bands which connect to the solid strip 'columns' in the walls.

The lightest weight box would be assembled from Hollow-core walls and Ceiling, and a Slab-band floor: *

For example, for a typical unit 36'-10" long and with an interior 13'-0" dimension:

Slab-band floor: 3"/6"	8.8 tons
Hollow-core wall: 4"	4.6 tons
	4.6 tons
Hollow-core ceiling: 4"	<u>6.7 tons</u>
	24.7 = 25 tons

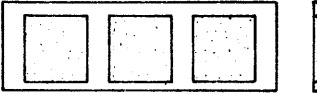

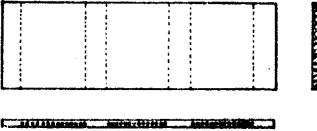
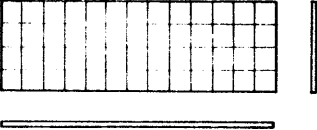
or about 2/3 ton per lineal foot; making the next box unit size of 45'-6" about 30 tons and the largest size of 54'-2" about 36 tons.

However, the average weight is about 1 ton per lineal foot of box unit length considering all types of slab construction. The typical unit 36'-10" could be more than 35 tons. Obviously, efforts should be made to make the box as light as possible and still achieve necessary strength and durability, and still achieve economy of manufacture.

*Hollow core walls can not be made with existing extrusion equipment and would be more expensive than flat slabs regardless of weight savings. Only good for walls with no openings.

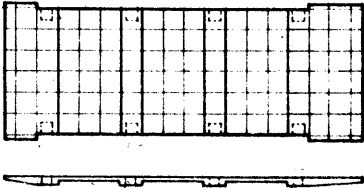

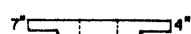
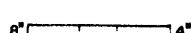
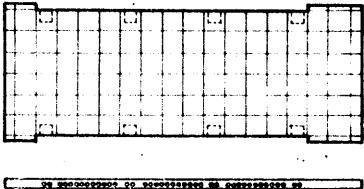
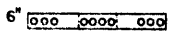
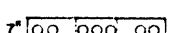
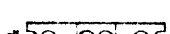
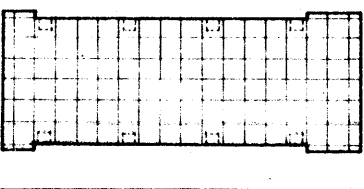
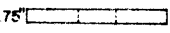
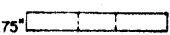
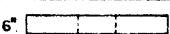
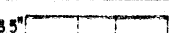
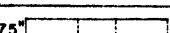
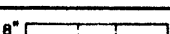
WALLS

WEIGHT IN TONS
NO ALLOWANCE FOR OPENINGS
9'-0" WALL HEIGHT

			PSF	15'-6" 175.5sf	28'-2" 253.5sf	35'-0" 331.5sf	45'-6" 409.5sf	54'-2" 487.5sf
infill: panels or pour  Cellular Concrete infill between structure	4"							
	5"		NOT YET TECHNICALLY & ECONOMICALLY FEASIBLE					
	6"							
ribs 	5" 3"		36.1	3.2 TONS	4.6 TONS	6.0 TONS	7.4 TONS	8.8 TONS
	5.5" 3"		38.2	3.4	4.8	6.3	7.8	9.3
	6" 3"		40.3	3.5	5.1	6.7	8.3	9.8
hollow core 	4"		28	2.5	3.5	4.6	5.7	6.8
	5"		36	3.2	4.6	6.0	7.4	8.8
	6"		44	3.9	5.6	7.3	9.0	10.7
solid slab 	4"		36.8	3.2	4.5	5.9	7.5	9.0
	5"		46.0	4.0	5.8	7.5	9.4	11.3
	6"		55.2	4.8	6.9	9.7	11.5	13.6

FLOORS

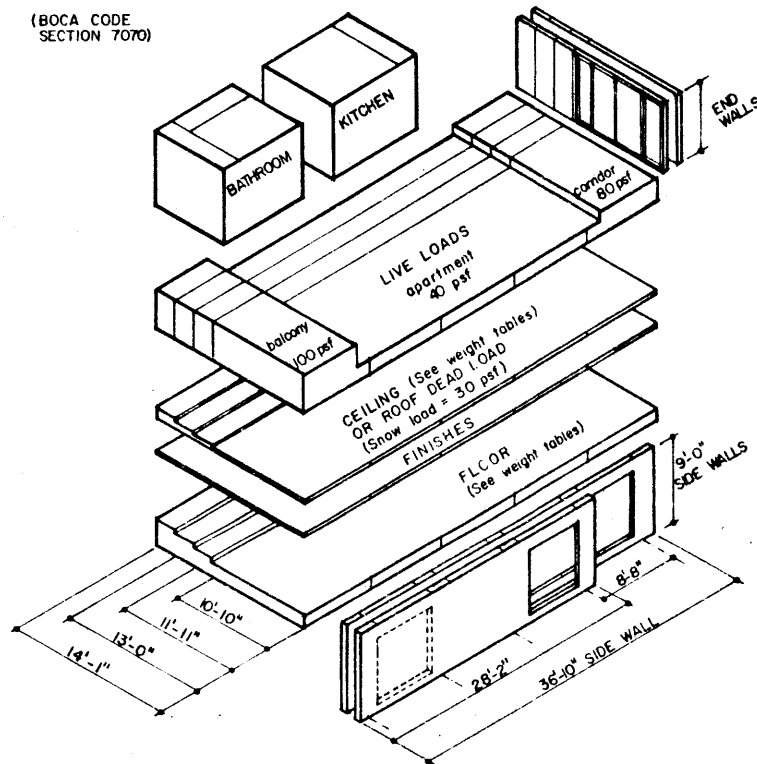
WEIGHT IN TONS
13'-0" FLOOR WIDTH

		Light weight structural concrete 110 pcf (9.2 psf per inch thickness)						
		Max span	PSF	19'-6" 253.5 sf	28'-2" 366.2 sf	36'-10" 478.8 sf	45'-6" 591.5 sf	54'-2" 704.2 sf
slab-band 	6" 		36.8	4.7 TONS	6.7 TONS	8.8 TONS	10.9 TONS	13 TONS
	7" 		45.4	5.8	8.3	10.9	13.4	16
	8" 		48.3	6.1	8.9	11.6	14.3	17
hollow-core 	6" 		43	5.5	7.9	10.3	12.7	15.1
	7" 		50	6.3	9.2	12	14.8	17.6
	8" 	20'-0"	57	7.2	10.4	12	16.9	20.1
solid slab 	4.75"  *	10'-10"	43.5	5.5	7.9	10.4	12.9	15.3
	5.75" 	13'-0"	52.9	6.7	9.7	12.7	15.6	18.6
	6" 	14'-1"	55.2	7	10.1	13.2	16.3	19.4
	6.5" 	15'-2"	59.8	7.6	11	14.3	17.6	21.1
	7.5" 	17'-6"	69.0	8.7	12.6	16.5	20.4	24.3
	8" 	18'-8"	73.6	9.3	15	17.6	21.8	25.9

* Source STRUCTURAL DESIGN GUIDE TO THE ACI BUILDING CODE TABLE 3-3

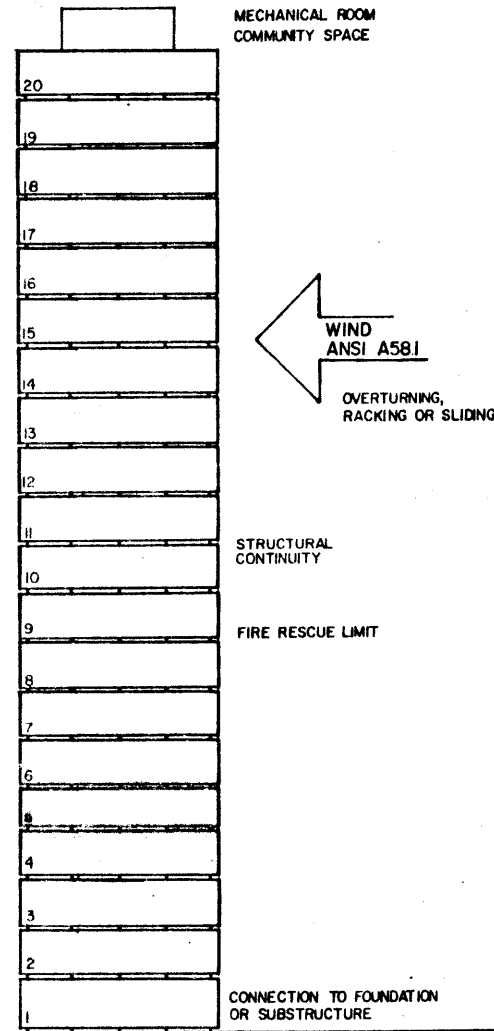
LOADS

(BOCA CODE
SECTION 7070)



AVERAGE 13'-8" WIDE BOX-UNIT WEIGHS 1 TON PER LINEAR FOOT.
SEE FOLLOWING CALCULATIONS.

20 box units = 700 TONS



EARTHQUAKE (U.B.Code latest issue)
GROUND SETTLEMENT

STRUCTURAL CONSIDERATIONS

Besides taking into consideration basic assembly methods and types of box-units, attention must be given basic structural behavior.

"Statical and constructive questions...which are typical of a precast reinforced three-dimensional construction are:

1. The buckling of the walls;
2. The eccentricity in the walls.
3. The support conditions and the loads between the units".*

According to Joseph Varsano, "even if support is carried out in an ideal way and eccentricity is nil from the point of view of the passage of force between the upper storey wall and the lower storey one, even in this ideal case, there is great eccentricity following the moments operating on the walls as a result of the bending of the floor and ceiling."*

*Joseph Varsano, / Isreal/
"Statical Problems in Three Dimensional Precast Units", Paper II-13 presented at the International Symposium on Box-Unit Construction, Balatonfüred, Hungary, 1973; p. 1.

"In addition to the eccentricity following the bending, there naturally is a constructive and technical eccentricity owing to tolerances. As the thickness of the wall, for weight reasons, is much smaller than its height, in the ratio of approximately 1/25, there results a serious buckling problem...."

J. Varsano's paper details load capacity variance as a function of eccentricity and suggests thickening walls at the ends of boxes to increase moment of inertia, or to use the four walls as constructive ones.

Walls can be stiffened by increasing the dimensions, adding ribs or pilasters, or connecting walls of adjacent box-units with a device that enables them to act as a single, thicker wall or braces them at required intervals. The latter methods have been outlined by Prof. W. Zalewski of M.I.T.

This paper presents some calculations for the OFFSET System proposed herein on page 172, to give a rough idea of building height and stability. Due to time limitations, calculations for wind stability are not presented.

PRELIMINARY EARTHQUAKE STABILITY CALCULATIONS

Assume the coefficient c established by Building Codes will be 5% = .05 for the location given.*

Let W = mass or weight of building.

According to the proportions of the triangles, the limit of stability = $d/6$ (with 1/6 eccentricity considered maximum allowed)

$$d/6 : cW :: 2/3 H : W$$

$$\frac{dW}{6} = \frac{cW}{3} \cdot \frac{2H}{3}$$

$$d/H = 4c$$

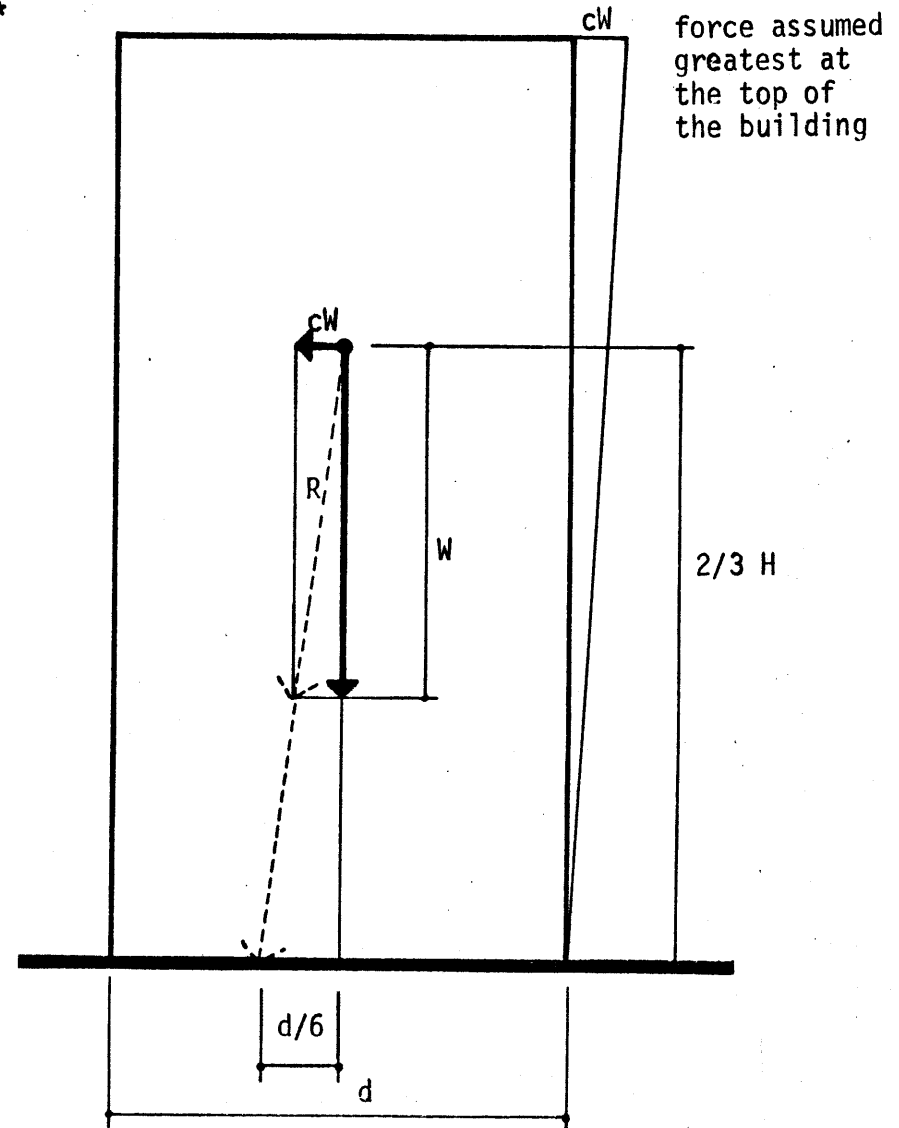
When $c = .05$, $d/H = .2$ or $2/10$

The ratio of depth to height must be 2:10

If the maximum building height is 20 floors or 180 ft., then the minimum depth must be 36 ft. to resist earthquake forces in the location given.

Note: Some authors propose the use of vertical post-tensioning when the building is over 5 floors high. [25]

*Depending upon the seismic region, the coefficient could range up to 10%.



MAXIMUM NUMBER OF FLOORS

Assume average box wt. = 30 tons
= 60,000 lbs.
= 60 kips.

A 28'-2" box has four bearing plates, each side. Each plate carries $60/8 = 7.5$ kips on an area $4" \times 25" = 100$ sq.in.

Assume $f' = 4,000$ psi; $f_a = 1,500$ psi
(ACI CODE 1971)

Each support can carry $P_a = \text{Area} \times f_a$

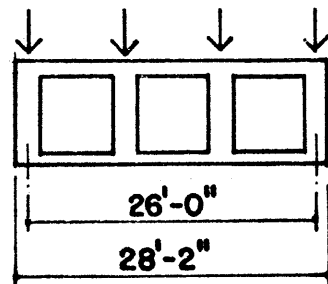
100 sq. in. $\times 1,500$ psi = $150,000$ lbs.

Therefore, 150 kips can be carried at each support. Since each floor contributes 7.5 kips at each floor, the maximum no. of floors will be approximately:

$$150/7.5 = 20 \text{ floors}$$

If f_a is assumed to be 1,000 psi instead of 1,500 psi only 100 kips can be carried at each support, and the no. of floors will be approximately:

$$100/7.5 = 13.3 = 13 \text{ floors}$$



WALL THICKNESS

"When designed by the empirical method, the ratio of the unsupported length to thickness l_c/h cannot be more than 25 or 30 for panel and enclosure walls, unless it can be shown by a structural analysis that adequate strength and stability will exist at greater ratios." [23]

"Load bearing walls can all be designed by the rational method, or by the empirical method only if the eccentricity of the load is equal to or less than one-sixth of the wall thickness!" [24]

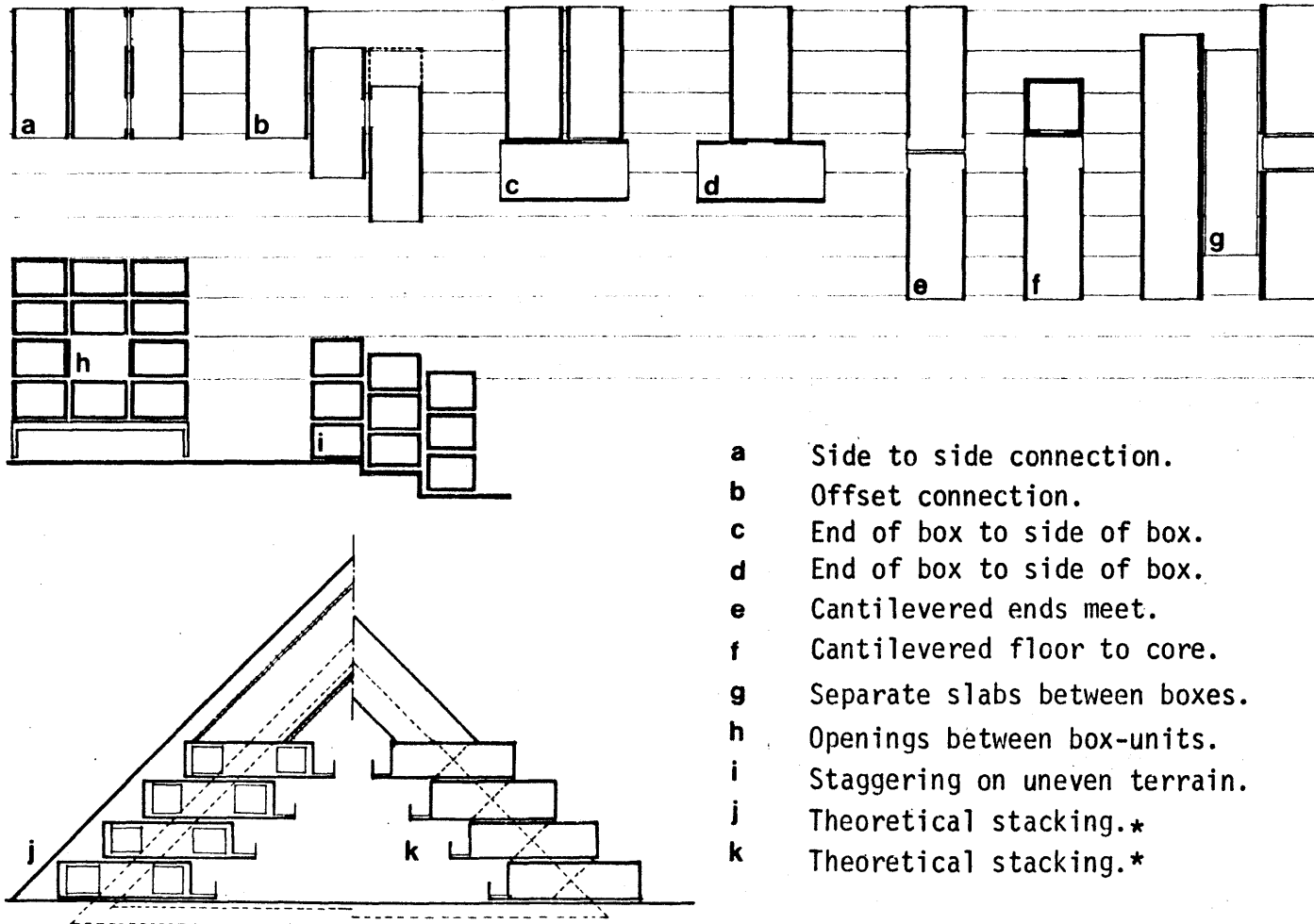
Assuming the empirical method applies,

$$l_c = 8'-0" \text{ unsupported clear height} \\ = 96"$$

$$\text{So: thickness } h = 3.84 \text{ min.} = 4"$$

NOTE: Using lightweight (110 pcf) concrete and taking account the reduction in Modulus of elasticity, the effects of buckling and eccentricity, Prof. Zalewski has shown the allowable f_a could be in the range of 800 psi-- using a more critical box-unit length, the height of the building may attain only 10 floors.

CONNECTION CONDITIONS



- a Side to side connection.
- b Offset connection.
- c End of box to side of box.
- d End of box to side of box.
- e Cantilevered ends meet.
- f Cantilevered floor to core.
- g Separate slabs between boxes.
- h Openings between box-units.
- i Staggering on uneven terrain.
- j Theoretical stacking.*
- k Theoretical stacking.*

*Details or feasibility not developed.

The industrialized box-unit should anticipate all the connection conditions that will occur for as wide an application as possible.

These connections include the types shown on the opposite page.

In addition, connections for various types of roofs, exterior cladding, and sub-structures have to be considered.

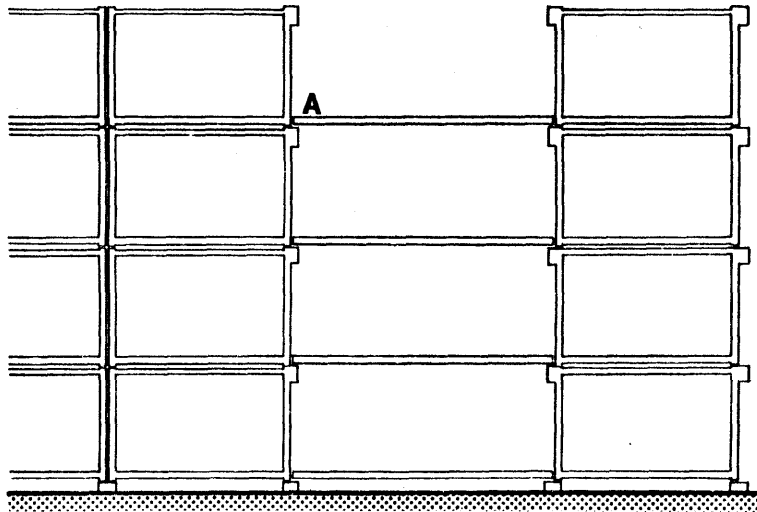
Various types of roofs are shown on page 215.

Exterior surfacing can be applied by spraying on stucco or concrete, fastening large panels of masonry or other material, or simply providing the surfacing for end units as an integral part of the box-unit.

The concrete box-unit has an advantage in that it can be used as a foundation by thickening and waterproofing the walls. Units can be set into hillsides, and have dirt covering the roof for gardens.

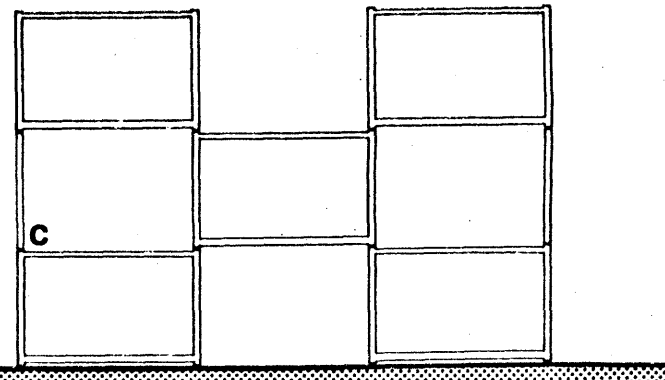
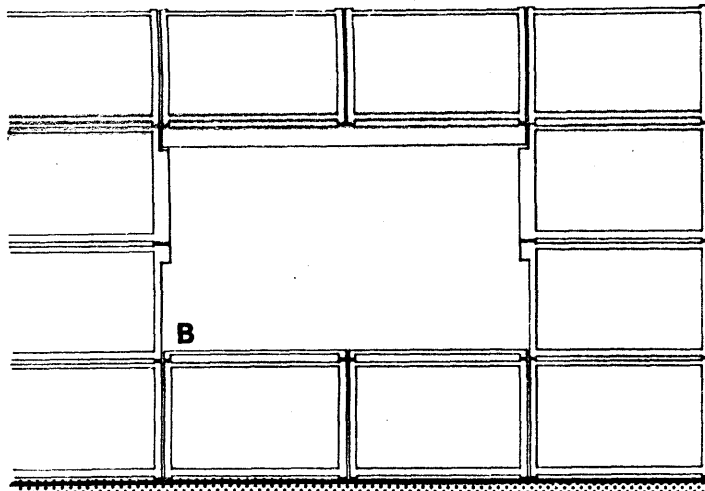
Conditions where box-units are to be elevated on pilotis are best solved when the ribs can be filled with concrete as shown on pages 152 and 153. . Also, hollow core walls can be grouted for vertical continuity. Special panels or space frames could be prefabricated or cast-on-site to carry the loads which occur at the regular intervals.

OPENINGS

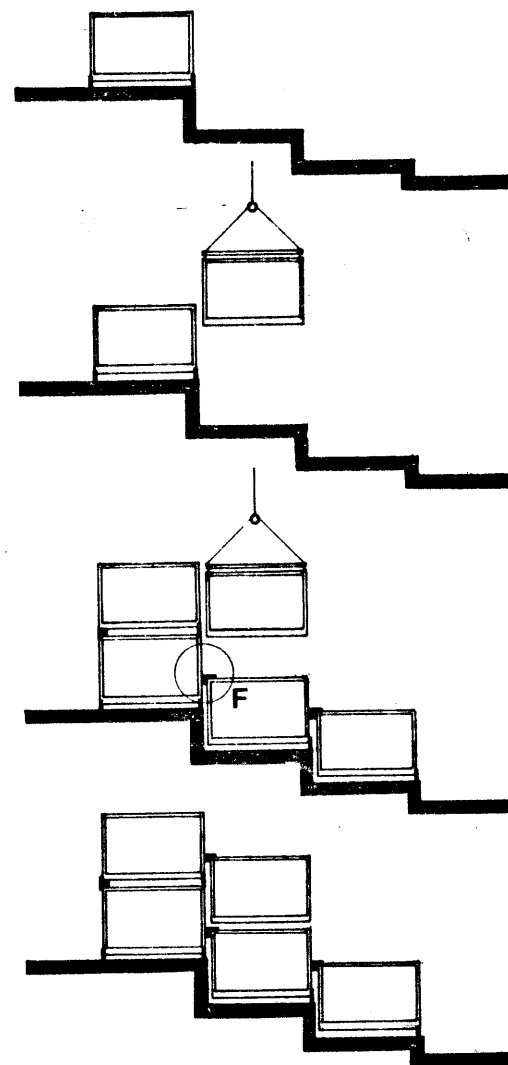
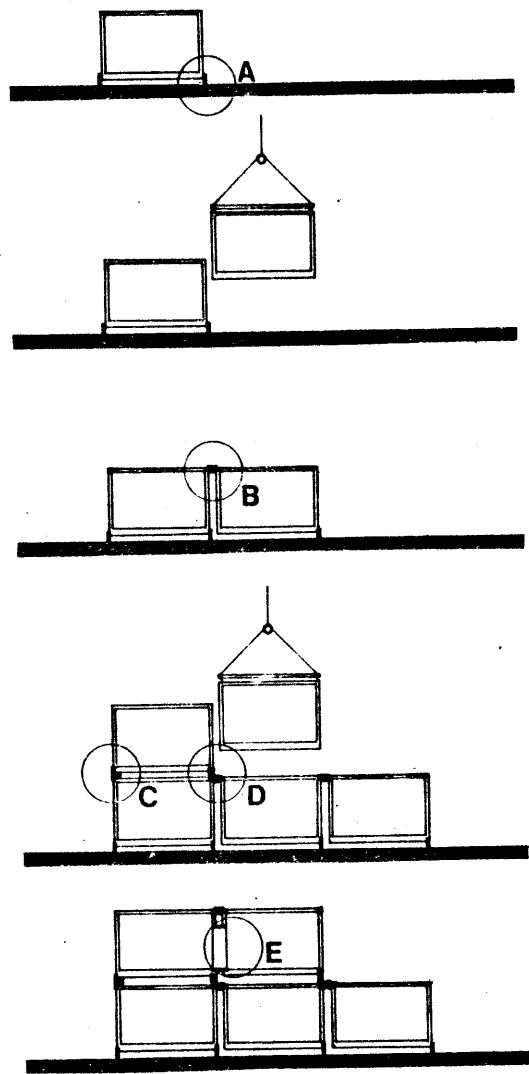


Openings between box-units can create passageways, large living spaces, terrace gardens, etc.

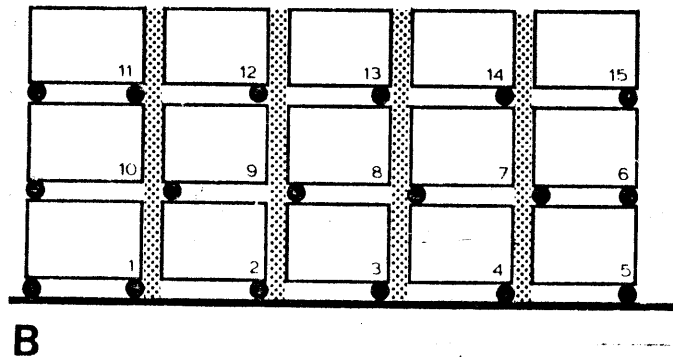
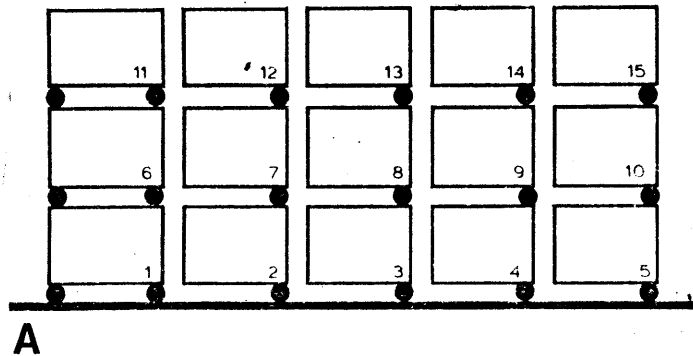
Figure A is adapted from an idea by Prof. W. Zalewski;
Figure B is a variation for a 2-level space, and Figure C shows a staggered checker-board with bearing walls. The lower level, with a thicker ceiling could be used as a patio or garden.



LEVEL OR STAGGERED STACKING



PREFERRED: STACKING SEQUENCE B



One of the problems which occurs when any connections are to be made between box-units on site, is location of access.

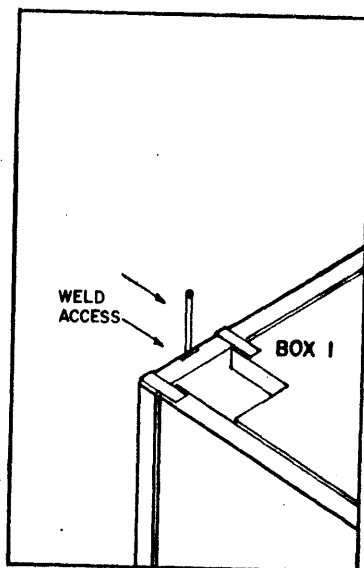
This problem is avoided when box-units span from front to back with only four supports which are accessible from the ends.

Welds between boxes may not be absolutely necessary, but they do provide an extra rigidity and thus increase the safety margin.

Box-units can be placed in sequence as shown in Figures A or B. The small circles note where side welds can be made. (Top welds can be made at any location, so they are not shown.)

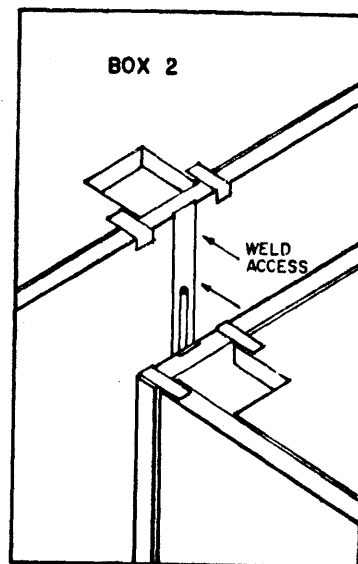
THE ARRANGEMENT SHOWN IN FIGURE B ASSURES CONTINUOUS ATTACHMENT FOR A ROD OR BAR WELDED OR OTHERWISE SECURED AS SHOWN IN THE DETAILS OF CONNECTION ON PAGE 179 WHICH CAN BE USED FOR BOX-UNITS ON LEVEL OR UNEVEN TERRAIN.

DETAIL 1: For Staggered (example shown) or Aligned Level Box -Units

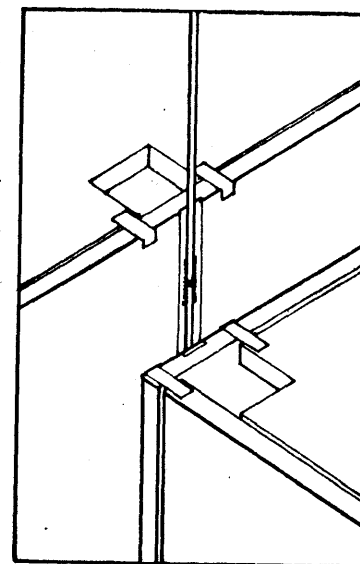


Place Box 1.

Steel rod or bar is spot welded to a steel plate cast into the sides of the box-unit at 8'-8" intervals.



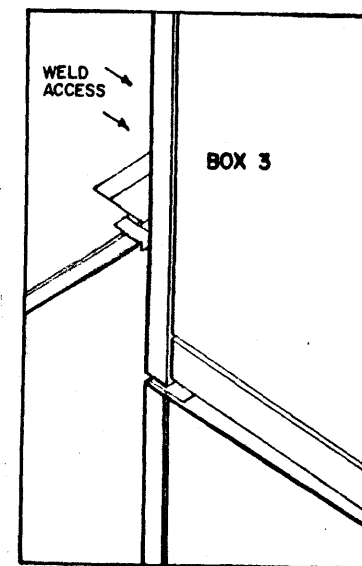
Box 2 placed any distance above Box 1.



Rod or bar is welded to opposite side of Box 2.

Extension allows continuity to roof.

Seal and apply grout.



Box 3 placed.

Steps repeated.

DETAIL 2

4" LT. WT. REINFORCED CONCRETE WALLS

OPTIONAL WELD AT OPENINGS

1" TOLERANCE BETWEEN UNITS

FINISH FLOORING

6" HOLLOW CORE CONCRETE FLOOR

WELD PLATES CAST INTO CONCRETE

GROUT COVERING WELDS

BEARING PLATE WITH BOLTED
CONNECTION BETWEEN
BOX 1 AND BOX 2

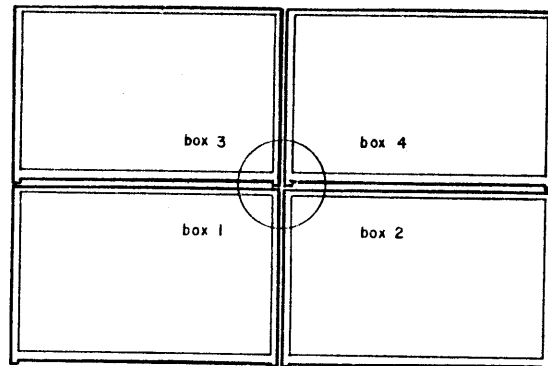
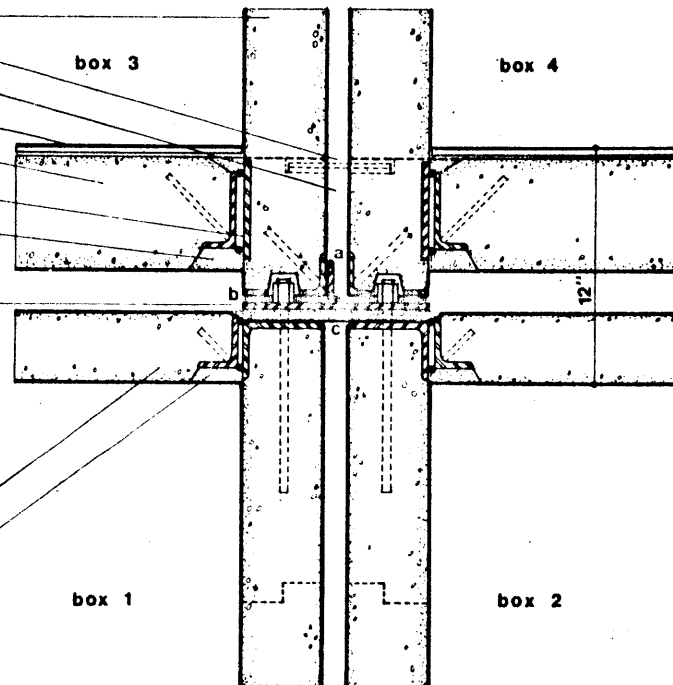
STEEL BAR WELDED TO BOX 3 (a)

NEOPRENE BEARING PADS (b)

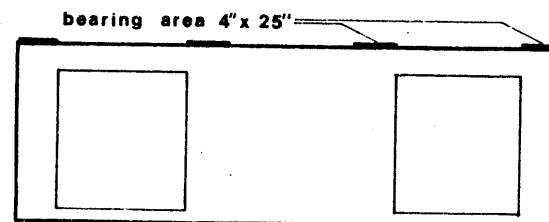
NON-SHRINKING GROUT (c) UNDER
BEARING PLATE AT HEIGHT OF
STEEL SHIMS. [Sealant in tape
form to run length of boxes.]

4" HOLLOW CORE CEILING

CORNER ANGLES AT SUPPORT POINTS

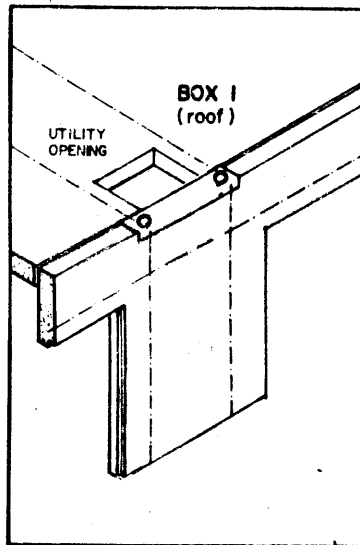


FRONT



SIDE

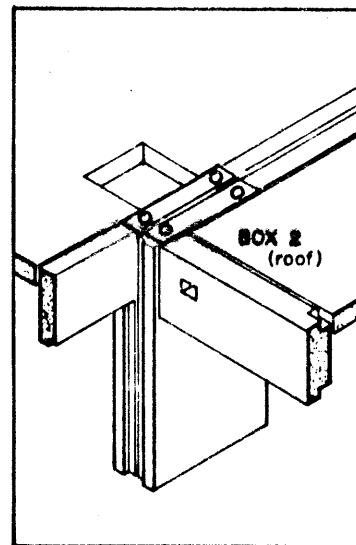
SEQUENCE: FOR DETAIL 2



Place Box 1.

Connections occur at 8'-8" intervals.

Dashes indicate the location of major reinforcing steel.

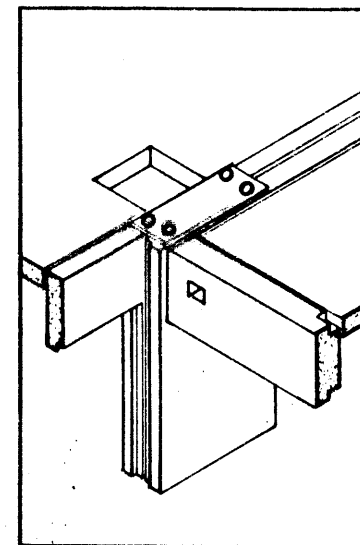


Place Box 2.

Apply steel shims if necessary.

Apply sealant to close joint between boxes.

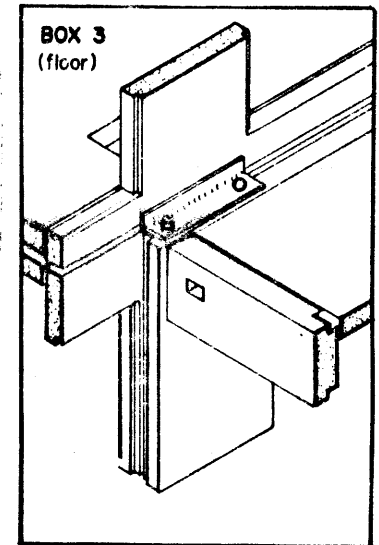
Place non-shrinking grout over bearing area.



Place 9" x 25" bearing plate.

Fasten bolts on protruding rods to link Box 2 to Box 1.

Place neoprene pad. Bolt acts as guide for Box 3.



Box 3 placed.

Weld plate is optional, depending upon local conditions.

Side weld can be made with a bar or angle.

SOURCES Chapters VI & VII

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- #3 Oktay Uray, Editor
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- #15 ARCHITECTURE PLUS Magazine May/June 1974
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FOOTNOTES

- 1 Source # 1 p. 45+
- 2 Source # 3 p. 213+
"The Logic of a Solution"
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Rich, Jr.
- 3 Source # 4 p. 32
- 4 Source # 5
- 5 Source # 6
- 6 Source # 7
- 7 Source # 5
- 8 Source # 5 p. 187
- 9 Source # 6
- 10 Source # 8
- 11 Source # 9 p. 526
- 12 Ibid.
- 13 Source #11
- 14 Source # 5
- 15 Source #12 p. 117
- 16 Source #15 p. 89
- 17 Source #14
Paper II-6 Variel System
H. Grässl, Switzerland
- 18 Source #12, p. 120; also
Source #2
- 19 Source #12 p.132
SIC System
(also described in
Source #14)
- 20 Source #12 p.144
DISKIN System
- 21 Source #12 p.131
- 22 Source # 9 p. 531
- 23 Source #16 p. 317
From ACI CODE Sections
14.1.2, 14.2-d, and 14.2-j.
- 24 Source #16 p. 317
ACI CODE Section 10.16
and 14.2

VIII. Subsystems and Components

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Subsystems

FOUNDATIONS

"Use of the concrete box as a foundation is ideal for hill sites where the foundation can also serve as living space. One end of the box can be punctured for windows. Since the concrete module is three-dimensional, it can be used for earth retention and thus eliminate the need for the usual and expensive retaining walls. The modules, with integral columns in the walls to receive point loads, create a strong and economical base for the stacked modules above". [1]

The box-unit could conceivably be placed on a gravel base, eliminating the usual slab on grade or perimeter walls and piers.

When modules are raised above ground, columns and panels can be used. The best type wall section to use in this case would be a ribbed type as shown on page 152 .

A deeply coffered floor slab would serve as a 'floating raft' in some soft soils.

Prof. Kenneth F. Reinschmidt calculated the effect of box-system dead weight on foundation costs for the MIT INDUSTRIALIZED HOUSING FEASIBILITY STUDY of 1971. [2]

His assumption was based on concrete units weighing 30 tons each and lightweight boxes weighing 6 tons each, used for a sample 7-story building and others as given in Fig. 8A11.1 of that study.

For the 7-story building, the foundation cost premium for the concrete system would be \$0.19 /sq.ft. with 200 psf deadweight and \$0.31 /sq.ft. with 235 psf deadweight.

Other cost comparisons between hand-crafted concrete and steel-framed boxes are included in the MIT STUDY [3] and other information attempting to compare costs may be found in Terry A. Louderbach's Thesis at MIT. [4]

ELECTRICAL

ELECTRICAL SUPPLY
COMMUNICATIONS SYSTEMS
TELEPHONE WIRING
TELEVISION CABLES
DETECTION SYSTEMS:
fire, smoke, security

Electrical services are easily run throughout the box-unit and the building; although careful planning must be done to assure access to wiring for periodic checks and required repairs, and perhaps future replacement. Therefore, the electrical service should preferably NOT be embedded into the concrete slab unless some means of access can be found.

Several manufacturers offer modular type circuitry. One proposal for OPERATION BREAKTHROUGH for lightweight modules or box-units was an electrical harness which featured pre-assembled electrical wiring draped over the roof (the ceiling) of the unit. [5]

If box-units do not have large openings, a logical wiring device is the base-board plug-in strip, with switches let into door frame. With this type of method, special door frames must be used to take wiring around the door opening.

For concrete boxes with large side openings, another method of wiring would be to run a valance strip at the 7'-0" level. This valance could be a decorative feature to conceal the wiring, provide plug-in outlets for adjustable and relocatable light fixtures, and even conceal hot and cold water pipes and fire detection devices or sprinklers. This method is compatible with the concrete box-unit proposed in this paper since openings are 7'-0" high so there is always a 'beam' at the side and front of the box-unit.

LIGHTNING PROTECTION

Lighting protection devices will be secured as an on-site operation.

WATER SUPPLY

Each box containing either a kitchen or a bathroom must have provisions for pipes supplying water. Furthermore, if a heating system is chosen which depends upon a supply of hot or cold water from a central facility, some means must be found to bring the pipes to the front of the apartment. This can be accomplished by bringing pipes between boxes (best at party walls where there are no openings) or having a vertical shaft at the facade which leads directly from a mechanical space on the rooftop or in the basement, along the perimeter of the building. If floor-to-floor height is not critical, a suspended ceiling can be introduced. Also, the pipes can be concealed in a strip within the box-unit itself at the height of the door.

WASTE DISPOSAL

Disposal of liquid wastes is discussed in the section on plumbing which follows.

Disposal of solid wastes is usually done outside of the box-unit itself. One convenience that could be considered for the dwelling is a trash compactor.

Solid wastes can be dropped in a trash chute located near a 'core' for stairs or elevators and other vertical services.

The pneumatic trash conveying system is available from ECI AIR-FLYTE Corporation of Fairfield, New Jersey. The system consists of conventional gravity trash specially designed sizing and receiving hoppers, a pneumatic conveying system and a waste holding area containing large compactors with roll-off containers. [6]

Waste is placed in the gravity trash chutes, or directly into receiving hoppers in the required areas. Waste is automatically sized and transported under high negative pressure in any direction for the required distance.

The TAISEI CORPORATION of Tokyo, Japan plans to install its new pneumatic system in high-rise apartment buildings in Osaka, Japan in 1975. After nearly a year of test operation, the system has shown it can transport moisture-heavy garbage as well as fist-sized rocks, beer bottles and telephone books.

From chutes, refuse is sucked through pipes 16 to 24 inches in diameter to an intermediate point where air and garbage are separated. Air passes through a filter and it is cleaned to be released or utilized for the pressurized conveyor to the incinerator. The garbage can travel through the pipes at speeds of 6.5 to 10 ft. per second in the 1,150 ft. long tubes tested.

Although the system is expensive, it is expected to pay for itself within six years. [7]

FUEL SUPPLY

Regardless of the type of fuel used for heating, cooling, clothes drying, cooking, etc., it will be conveyed into the apartment unit by either pipes or wires.

As shown in the chart opposite, electricity is the most widely used fuel type at the source of use in privately owned multi-unit dwellings in 1973. However, the high cost of generating electricity may change this trend.

According to the Pratt Institute Study, the most economical heating system considering first cost and operating cost appeared to be a gas-fired sealed-combustion through-wall unit in each room. Electric radiant heaters are lower in first cost, but higher in operating cost. [8]

When air-conditioning is required, the electric utility may offer reduced rates during the heating system to balance the demand on its capacity necessary to supply electric power during the summer. [9]

Not considering costs, the electric heating and cooling systems are ideal for box-unit application since they are self-contained and require the minimum on-site connections.

Residential Energy Requirements estimated by Arthur D. Little, Inc. for 1972 presented by Professional Builder Magazine, February, 1975, p. 38 shows:

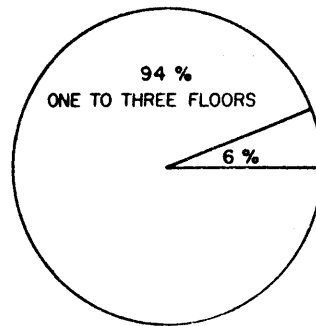
SPACE HEATING ENERGY REQUIRED	58%
LIGHTING AND APPLIANCES	22%
WATER HEATING	16%
AIR CONDITIONING	4%
	<hr/>
	100%

1972: 16.7 Quadrillion BTU

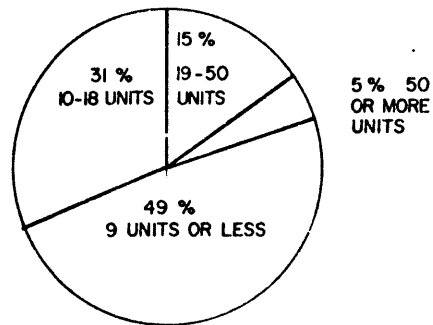
By fuel type, the breakdown is

GAS:	35%	(7% water heating, 28% space heating)
ELECTRICITY	37%	(22% lighting & appliances 7% water heating 4% air conditioning 4% space heating)
OIL	27%	(25% space heating 2% water heating)
COAL	1%	(1% space heating)
	<hr/>	100%

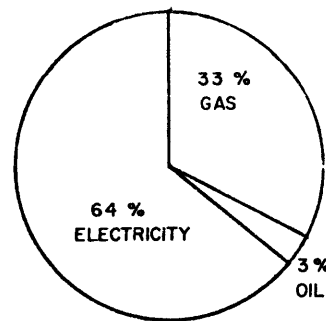
To provide for the addition of solar energy as a source of fuel, the system as applied to multistory dwellings should be able to accommodate the addition of hot and cold water pipes and provide access for heating/cooling equipment at window-walls.



Number of floors



Number of units



Heating fuel type

CHARACTERISTICS OF NEW PRIVATELY OWNED MULTI-UNIT DWELLINGS, 1973 .

SOURCE "CHARACTERISTICS OF NEW MULTI-UNIT RESIDENTIAL BUILDINGS, 1973"
U.S. DEPT. OF COMMERCE, CENSUS BUREAU, SUPPLEMENT C20-74

HEATING & COOLING SYSTEMS FOR APARTMENTS

Six heating/cooling systems are briefly reviewed in the following section. These are

1. Radiant Heating
2. 'Valance' Heating/Cooling
3. PTAC with baseboard heaters
4. Vertical Fan Coil Units
5. Cabinet Fan Coil Units
6. Balcony Unit. (Mixed types)

Central systems requiring ductwork for air handling are not included: unless the floor-to-floor height is increased 8" to 12" they would not fit.

All piping and ductwork is generally run vertically along the perimeter of the building so as not to cut down on interior closet and room space.

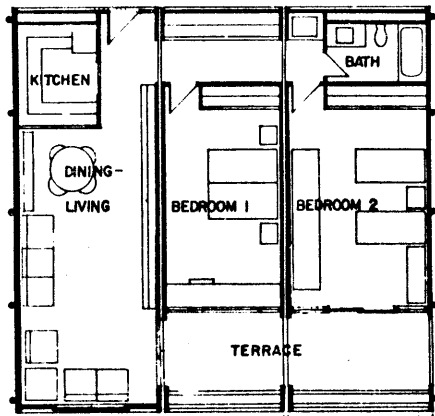
Horizontal ductwork or piping, except over corridor ceilings, is generally avoided in apartment buildings.[10]

Heating and air-conditioning equipment is usually located in the basement, with the cooling tower on the roof. Central heating can be provided with gas-, oil-, or coal-fired boilers.

Because of the effects of wind, rain and the stack effect, through-the-wall units are not recommended for buildings over 20 stories high. [11]

If air-conditioning is not initially provided, sleeves for tenant-supplied units can be provided. Also, an exhaust fan could be installed to remove odorous and smoky air. Windows should open for fresh air.

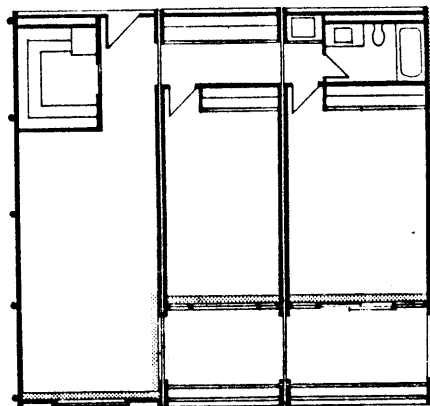
The system preferred for use with the concrete box-units detailed would be the 'Valance' Heating/Cooling System because of it adapts to all interiors, including those with sliding glass doors onto balconies and those with desks across the front of the box. Also, it would have low life-cycle costs and provides both heating and cooling. The system could be converted easily if water heated by solar energy became available in some future time.



RADIANT HEATING

Heating with radiant panels or cables imbedded in concrete offers the best visual system: nothing interferes with drapes, furniture, or large floor-to-ceiling glass areas.

However, this system is not popular due to initial installation difficulties and slow heating response in coming to full output. Cooling is by another method.



'VALANCE' HEATING AND COOLING

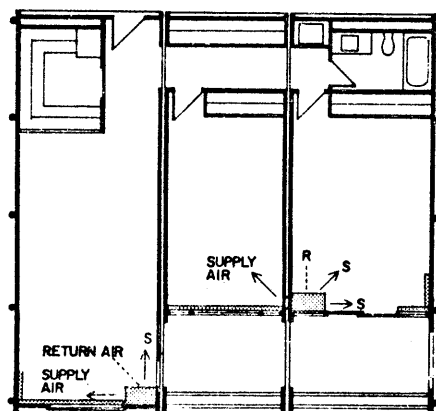
Next to radiant heating, the 'valance' system by the Edwards Engineering Corporation [12] offers greatest planning freedom.

A Valance Unit is a convection operated device mounted at the intersection of any wall and ceiling. Water passes through finned transfer surface within the valance, creating a convection flow of air for heating or cooling the space as desired.

The central boiler and chiller can be arranged in a vertical or horizontal installation to supply either two-pipe or four-pipe systems.

The method is draftless, produces even floor-to-ceiling temperature, has excellent dehumidification on cooling cycle, and acts to filter the air. There is low operating and maintenance cost with no blowers, fans, or moving parts.

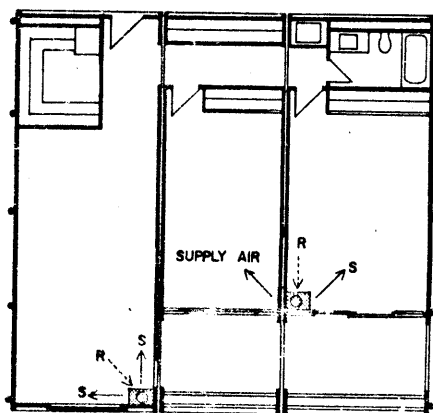
The system is silent, as opposed to fan-coil units which often produce 45-60 db sound levels. [13]



PACKAGED TERMINAL AIR-CONDITIONING UNITS WITH ELECTRIC BASEBOARD HEAT

Ease of installation.
Lowest first costs.
No central equipment or space required.
Electric consumption can be metered and charged to the individual apartment.
Tenant control of comfort.

Limited furniture and drapery placement.
High operating costs.
Air leakage in louvers.
Noisy equipment. [14]

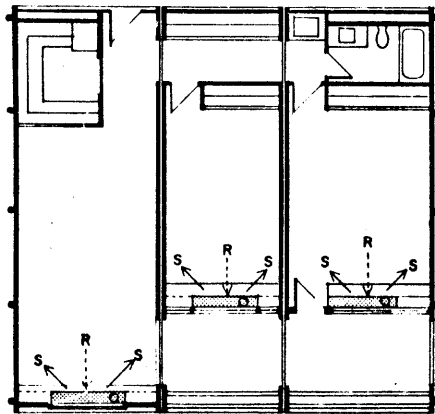


VERTICAL FAN COIL UNITS

Chilled water or hot water is supplied by a central chiller or boiler and distributed through a two-pipe factory-furnished riser system. An electric heating coil is furnished for intermediate supplemental heating during mild weather when the system has not been changed over from cooling to heating.

Pipes are factory fabricated to the exact lengths required, so on-site is minimized.
Low operating and life-cycle costs.
Requires central system change-over from heating to cooling in the spring.

Requires floor space.
Pipes must be run between box-units and connected.
Higher first costs than "A".
Whole system could breakdown. [15]



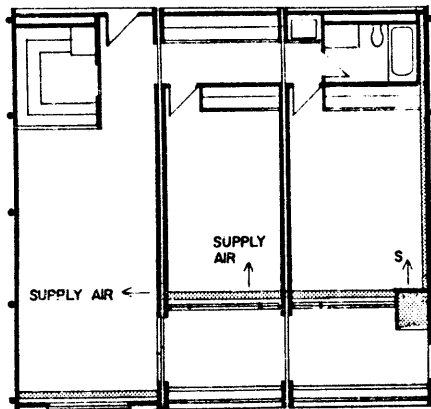
CABINET FAN COIL UNITS

Each box-unit contains a cabinet. Controls include a unit-mounted switch and a thermostat which controls an electric valve that meters the flow of water to the coil. Cold water is from chiller with cooling tower; hot water is from central boiler.

Fan coil systems allow for a lower total cooling capacity requirement, termed 'diversity'. The capacity requirements can be met with wide range of units.

Allows tenant control. Noise levels low because units don't have compressors. Fan coils can maintain closer temperature control since they can be modulated while the PTAC units cycle on and off. Unit mounted controls save field installation costs.

Limitations on drapes and furniture. Whole system can break down. Not good with glass doors. No ductwork is required, but riser supply and return piping must run to each unit. [16]



BALCONY UNIT





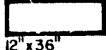
















The HVAC unit can be located in a special area on the balcony. The cooling unit has a compressor and evaporator coil, fan, motor and filter. An integral water-cooled condenser must be field-piped to a central cooling tower. Control is through a remote wall mounted thermostat, so its location is important. Air ducts can run outside or inside the box-units.

Increase of labor and costs associated with ductwork. Box-units must accommodate larger openings for ducts rather than pipes.

Tenant can control cost and comfort; air can be controlled.

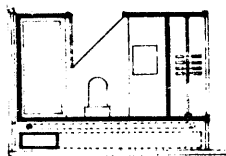
Balcony location saves interior space, but soffit is required.

DUCT SIZES

	SQUARE INCHES		SQUARE INCHES		SQUARE INCHES	
TO 21 FLOORS	210		483		714	
TO 18 FLOORS	180		414		612	
TO 15 FLOORS	150		345		510	
TO 12 FLOORS	120		276		408	
TO 9 FLOORS	90		207		306	
TO 6 FLOORS	60		138		204	
TO 3 FLOORS			69		102	

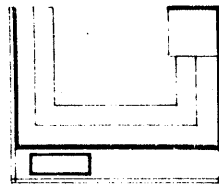
BATHROOMS

TO ALLOW FOR SOIL PIPES
TO PASS VENT DUCT, 10"
IS MAXIMUM INTERIOR WIDTH.

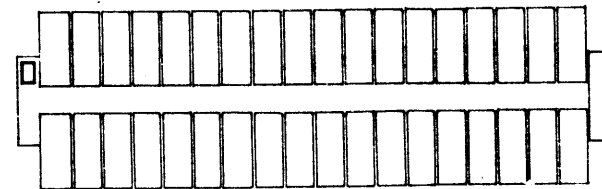


KITCHENS

14" IS MAXIMUM KITCHEN VENT WIDTH.
NOTE THAT RATIO OF LENGTH TO
WIDTH DOES NOT EXCEED 3:1.



CORRIDORS



VENTILATION

FHA Minimum Requirements for Multifamily Housing are given on page 71 in Table 4-3.1.*

Inside dwelling units:

Living rooms, dining rooms, bedrooms and other habitable rooms require ten (10) ventilation air changes per hour--supply or exhaust or provide summer air conditioning or cross- or through-ventilation.

Kitchens require eight (8) exhaust air changes--may be room controlled exhaust fan: wall or ceiling, 15 air changes per hour; range hood, 40 cfm per lineal foot of conventional hood or 50 cfm per lineal foot of hood for island or peninsular placement.

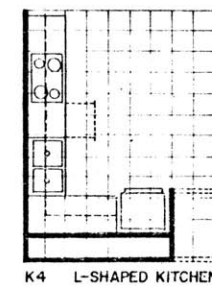
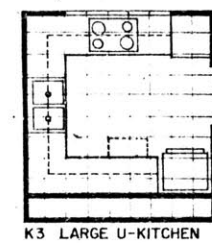
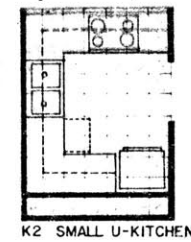
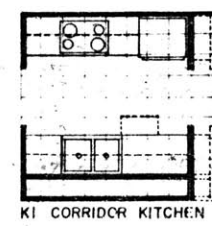
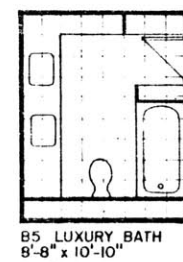
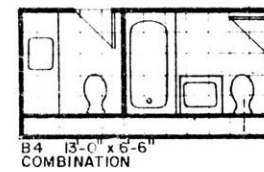
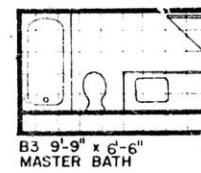
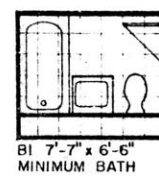
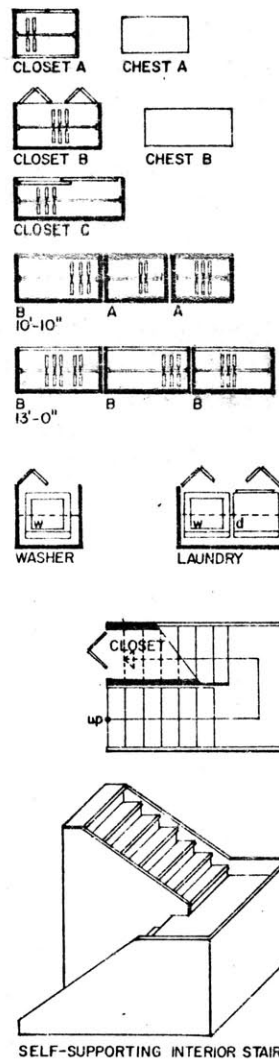
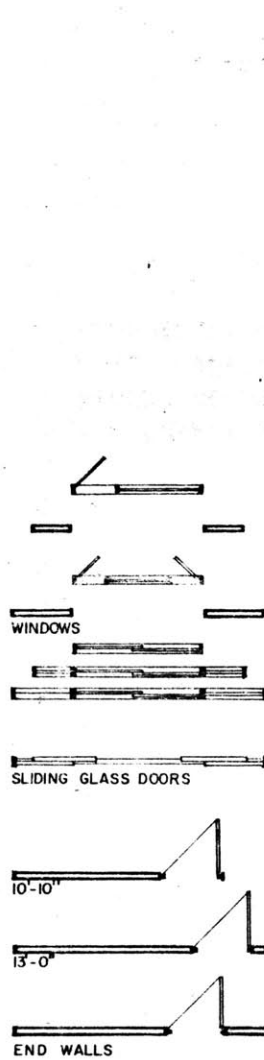
Baths require five (5) exhaust air changes--may be room controlled exhaust fan with 8 air changes per hr.

The chart opposite is adapted from TIME SAVER STANDARDS FOR BUILDING TYPES [17] and assumes

50 cfm of exhaust air per toilet.
150 cfm of exhaust air per kitchen. [18]

Corridors, stairs, and lobbies require four (4) supply air changes per hour--space shall not be used as supply or return air plenums for living units' ventilation.*

*From the 1973 Edition, HUD MINIMUM PROPERTY STANDARDS, MULTIFAMILY HOUSING, p. 4-27.



Standard Components

The standard components have been designed to fit a 13" grid module. They fit into the two box-unit widths of 10'-10" and 13'-0". The dimensions shown for the bathrooms are exterior dimensions in the case a 3-D bathroom unit is to be used.

Although box-units could be planned so two apartments could 'share' a box, none of the plans developed in this paper have this condition. Also, the plans are made so interior walls are not necessary--3-D closet components and door assemblies suffice to divide spaces not separated by bathrooms or kitchens.

The stair is a light-weight wooden self-supporting structure for use in two-level apartments. Another design would have to be used for three-level apartments or houses. Closet space is built into the space under the stairway.

The structural system has been planned so openings could accommodate two doors with a wall between, standard sliding glass doors, a stair way, and still not be of excess width for a corridor. This dimension was decided to be 6'-6". Windows in the side walls can be a maximum of 6'-6" wide. (That is, the masonry rough opening is that size).

The ends of the box-units could be light-weight weather screens or window walls. A series of standard window sizes would fit most requirements.

All the apartment types shown have been developed using these components, with the exception of special bath-laundry combinations with extra large doors for use by the handicapped or elderly, or for hospital design use.

Typical elevator and stair arrangements for tower-type buildings are shown on pages 232 and 233. Basic elevator and stair core types and locations are shown on page 228 for double-loaded corridor buildings, but only schematically.

Standard elevators are available from four or five manufacturers in this country. Stairways can be cast in adjustable molds or purchased from independent manufacturers.

Although fireplace details are not presented in this paper, there are a few prefabricated fireplace models and stacks which can be adapted for use in box-unit systems of all types.

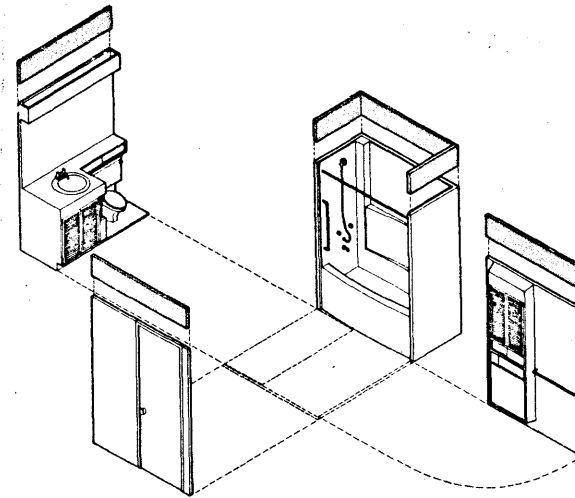
BATHROOMS

Bathrooms can be either assembled from component parts on the main assembly line, or placed in the box-unit as a pre-finished 3-d 'core' ordered from special manufacturers.

Advantages of component parts include ease of obtaining custom parts from a large selection of suppliers. There is more ease in changing models to suit different markets. One less wall and possibly one less ceiling is required. Also, floor-supported fixtures may be used. This advantage is important, because elaborate wall construction and bracing is not required.

Fixtures developed especially for concrete panel construction are well suited for box-unit use. This includes tubs with raised outlets that are supported on a special frame, floor supported water closets with back flush about 5" off the floor at the center of outlet, and lavatories built into cabinets.

Wall hung toilets and lavatories can also be used with special base supports anchored to the floor behind the wall to support the loads. This option, developed by the TYLER PIPE COMPANY and the J.R. SMITH COMPANY is often used in concrete panel construction. [19]



An example of the use of component parts used by DESCON/CONCORDIA SYSTEMS, LTD. of Montreal, Canada. Component parts are also used by many builders, including conventional on-site builders. The entire bathtub unit is available from several manufacturers molded from fiberglass reinforced polyester with fire retardants.

Three-dimensional bathrooms are now offered in this country by ALCOA CONSTRUCTION SYSTEMS, INC. of Pittsburgh, Penn. Standard models are offered in four series: the type for high-rise buildings is Series H. [20]

COMPONENTS, INC. of E.Chicago, Ill. will custom-build bathrooms (and kitchens) to any required specifications. Typical price for a sample bath in 1974 was given as \$1,500 including ceramic tiled prefab floor section, drywalled exterior and interior partitions with ceramic tub surround, usual fixtures, shelving, medicine cabinet, pre-installed plumbing tree and protective covering. [21]

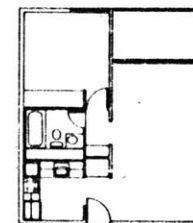
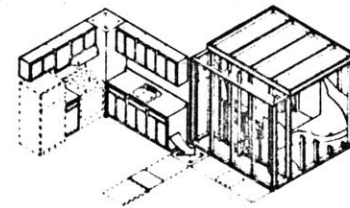
WESTINGHOUSE ELECTRIC CORP. has stopped producing the fiber reinforced polyester bathroom models designed by the ECHO MODULE SYSTEMS, INC. for its Weymouthport project. However, some firms in Germany are producing plastic bathroom 3-d units. [22]

Alcoa H-Series Service Modules are incombustible, nonloadbearing and designed for installation on structural floors of apartment buildings that are installed by others. These compact and lightweight modules are easily lifted by crane and maneuvered within the building to the proper location. ACSI can supply special lifting cages or moving tools if required.

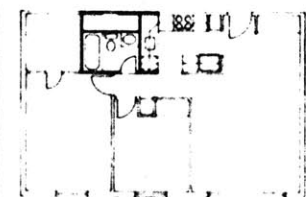
Modules are primarily finished bathrooms with plumbing installed in open chases for ease of hookups, inspection and testing after installation. The bathroom modules can be equipped with heating and cooling fan-coil units to add extra value to the package. Various compatible kitchen components are available.

Installation of Alcoa H-Series Service Modules can be sequential with the installation of other building components, or, preferably, the modules can be installed horizontally from the perimeter of the building after the structure is in place. When the modules are installed after the structure, they can be scheduled independently and the building tends to protect the modules from the weather and from construction damage. When installation is from the building perimeter, wall openings should be approximately 8 feet high and must be wide enough to accommodate the width of the module.

H-Series Modules work equally well in elevator apartments and walk-up living units. For best results and maximum cost savings, the modules should be located remote from party and corridor walls to eliminate redundancy and utilize the module as a design element as well as an operating core.



H701/One bedroom



H1002/Three bedrooms



H601 6x6



H602 6x7



H603 6x12



H701 8x7



H702 8x7



H801 8x8



H1002 8x10



H1201 8x12



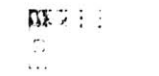
H701E 8x7
(Elderly)



H1001EH 10x7
(Handicapped)



HK801 8x2/6

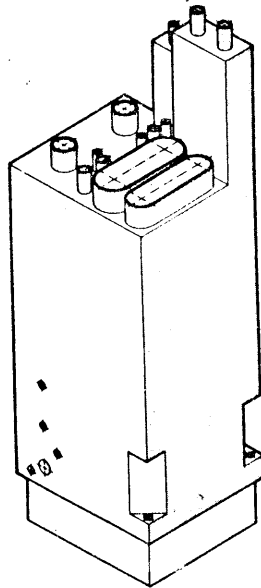


Loose cabinets

Shown above are ALCOA CONSTRUCTION SYSTEMS, INC. H-Series Service Modules for elevator and walk-up apartments, intended for concrete panel construction, but adaptable to other types.

DESCON/CONCORDIA SYSTEMS, LTD. offers a light-weight prefabricated mechanical services core for use in its high-rise residential buildings with concrete panel construction.[23]

The unit, shown below, is placed floor-to-floor and linked vertically with speed connectors. Water, drainage, venting, and electrical connections may be tapped on any of three faces.



Example of prefabricated mechanical service core from DESCON/CONCORDIA SYSTEMS, LTD.

Most mechanical core 3-D units are designed for use with panel-type construction. Another core unit for low-rise use is offered by COMBI-CORE of Jackson, Mississippi.[24]

Such a specialized unit may not be desirable or necessary when box-units are the type of construction utilized. When building with boxes, the box itself can provide support for pipes, vents, and so forth and the services would be contained rather than being a separate element.

For OPERATION BREAKTHROUGH, The Rouse-Wates Company proposed a single-stack plastic D.W.C. system which had been developed in Britain, using P.V.C. plastic soil and rain water pipes and C.P.V.C. plastic hot and cold water supply. Fire requirements were met by careful detailing of the penetration of the building systems. [25]

The Pratt Institute study of 1967 considered the use of three types of plastic pipe:

1. PVC (Polyvinyl Chloride),
2. ABS (Acrylonitrile-butadiene-styrene,
3. Bituminous fiber pipe. [26]

Although plastic pipes have the advantage of cheaper material costs, lighter weight, and simplified techniques of jointing, all plastic pipe is combustible to some extent. (P.V.C. will not support combustion, but the other types need some degree of fire protection.) "One solution is to fill the plumbing chase with a very light vermiculite concrete, which would not only give fire protection but also thermal insulation for the hot water supply lines and acoustical insulation. Plastic pipe has an extremely high coefficient of thermal expansion and must either be rigidly restrained or provided with a slip joint at each floor. Slip joints, formed by double neoprene O-rings, have been used in English and European practice and appear to be entirely satisfactory." [27]

The Uniform Plumbing Code used in 10 states and by communities in 25 other states presently permits the use of plastic pipe in mobile homes and single-family dwellings of up to two stories.

In October, 1974, the annual convention of the International Association of Plumbing and Mechanical Officials (IAPMO) rejected a proposal to amend the Code to allow plastic plumbing pipe in high-rise buildings. Fire department officials and plumbers unions opposed the change. Fire officials cited cases of plastic-related injuries to firemen, said that burning plastic pipe emits toxic gases, and that melting pipe can easily spread a fire when burning material falls on drapery and carpets. [28]

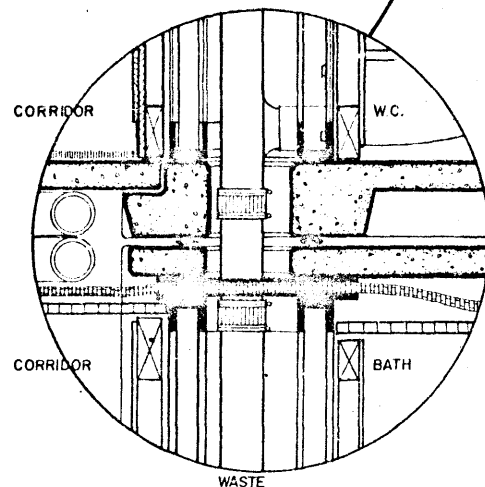
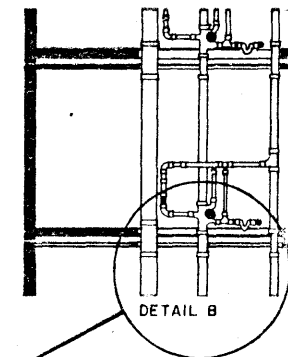
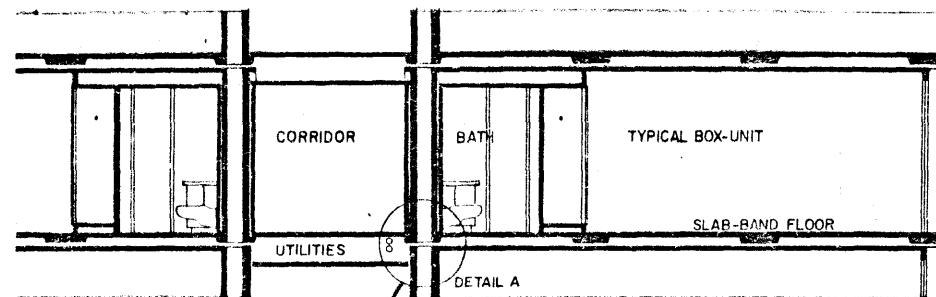
An amendment to the Housing and Community Development Act of 1974 restricted HUD (The Department of Housing and Urban Development) from imposing a model code on any community. [29] Previously, HUD could refuse to recertify cities' housing development programs, as required every two years, unless their codes eliminated bans on specific materials, such as aluminum wire, plastic-sheathed electric cable and plastic pipe.

The chemical solvents used to make joints in the pipes may also be suspect for harmful affects.

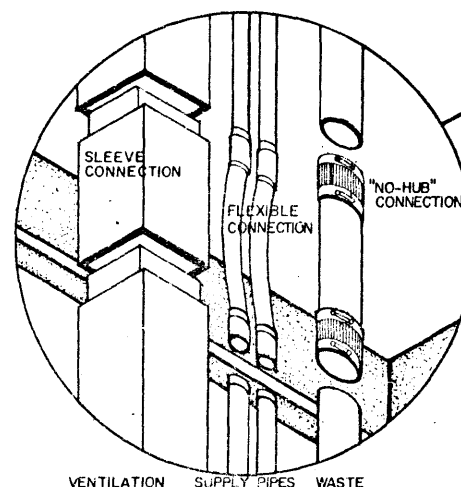
Vertical "No Hub" System

When utility spaces are vertically aligned, the design of drain, waste, and ventilation (dwc) systems follow conventional practice except for detailing on-site connections and providing fire stops and acoustical sealants.

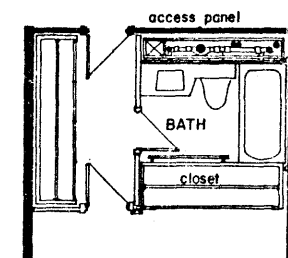
The TYLER "NO-HUB" waste system is shown.



DETAIL A SECTION BETWEEN BOX-UNITS AT CORRIDOR



DETAIL B VIEW OF UTILITY CONNECTIONS BETWEEN BOX-UNITS



ELEVATION OF PLUMBING WALL AND PLAN OF BATHROOM

Sovent System for Offsets

When the bathroom cores stack vertically, directly above the other, the design of the piping and other service spaces is relatively simple. However, when modules are stacked "imaginatively", offsets for pipes are required, and detailed planning is crucial.

Because the structural system here is planned so the offsets occur at 8'-8" intervals, the bathroom/closet and bathroom/dressing room areas are planned to occupy this interval along the length of the box-unit. This allows for two different types of offsets:

1. Dropped ceiling offset as shown on page 208 which requires a separate deaerator fitting at the horizontal stack offset and a lowered ceiling which can occur over the tub, in a closet, over a corridor, over a dressing room area, etc.
2. Slanted pipe offset as shown on page 209 which does not require a separate deaerator fitting if the pipes slope more than 30'. This type offset cannot be used to bridge modules over corridors.

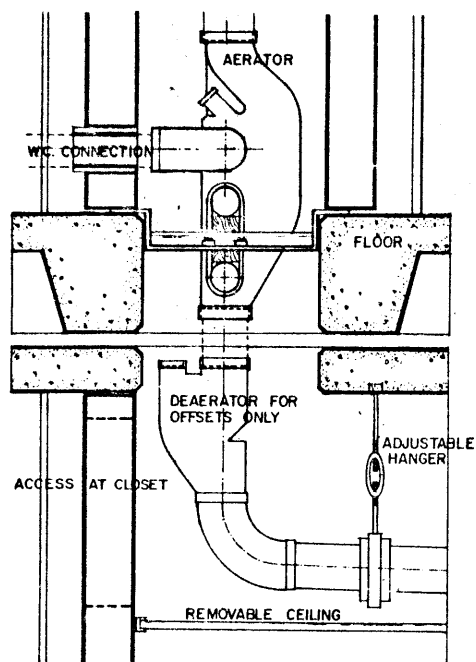
In most cases, only the plumbing assembly need be changed to convert a standard bathroom into one intended for use in "offset" box-unit modules. Although the basic bathroom layouts and fixtures are unchanged, more attention must be paid to fire-proofing in the "offset."

Since I wanted to investigate the most advanced technological developments commercially available today, a study of the SOVENT plumbing system is included, as well as the most recent conventional loop-vent types.

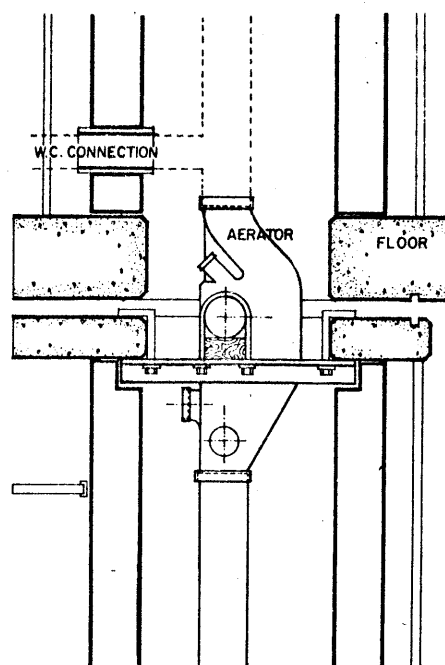
In 1961, Mr. Fritz Sommer, head of the department for sanitary installation at the Technical School in Bern, Switzerland, developed a new drainage system [30] that combines SOil stack and VENT into a single stack system that is self-venting with special fittings (aerator and deaerator) balancing positive and negative pressures at or near the zero line. This SOVENT system, available in copper, finally received approval of the American Standards Institute (ANSI) on January 18, 1973, and was accepted by the Southern Building Code Congress and 68 agencies (state, local, and municipal governments) to date.[31] It seems likely other codes will accept this system in the near future.

The SOVENT system is particularly suited for use with "offset" box-unit modules and fits well into conventional building types as well. However, other products and use of the traditional loop-vent system should be considered depending upon costs, performance, availability, and code-acceptance.

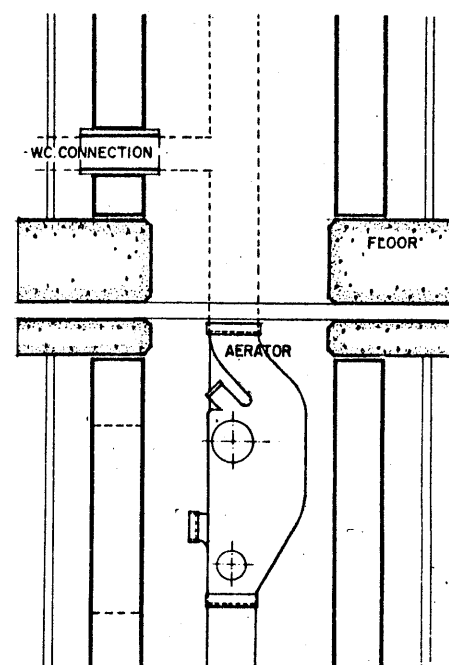
SOVENT APPLICATION



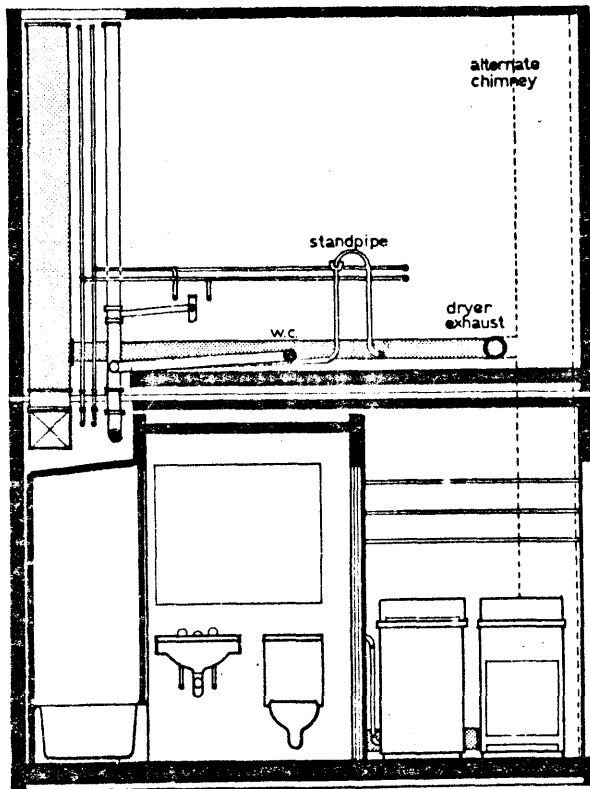
A This is the only location which allows enough headroom for the offset option when floor-to-floor height is 9'-0". Minimum depth for the floor construction will be 8".



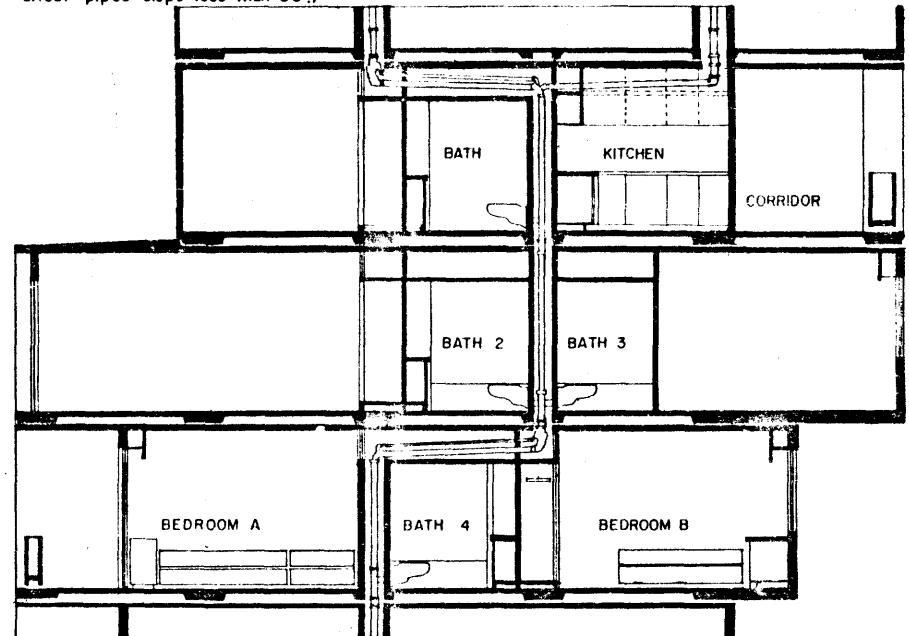
B If the aerator protrudes above the ceiling slab, access is easier but the fixture is likely to be damaged. Note decrease in slab thickness required.



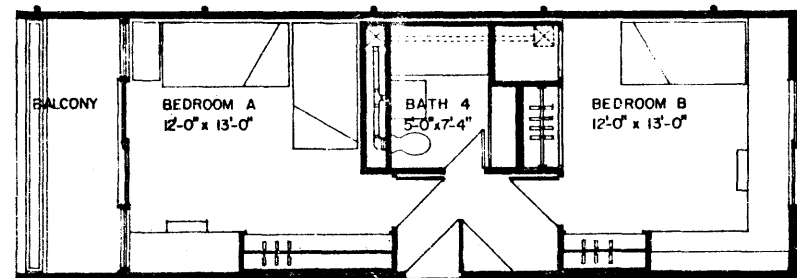
C Aerator fitting in lower box-unit is appropriate when plumbing is to be vertical, but a special condition results in the lower box-unit of the building.



(Deaerator fittings and vents are required where offset pipes slope less than 30°)



SECTION SHOWING POSSIBLE COMBINATIONS OF DIFFERENT BATHROOM TYPES AND LOCATIONS

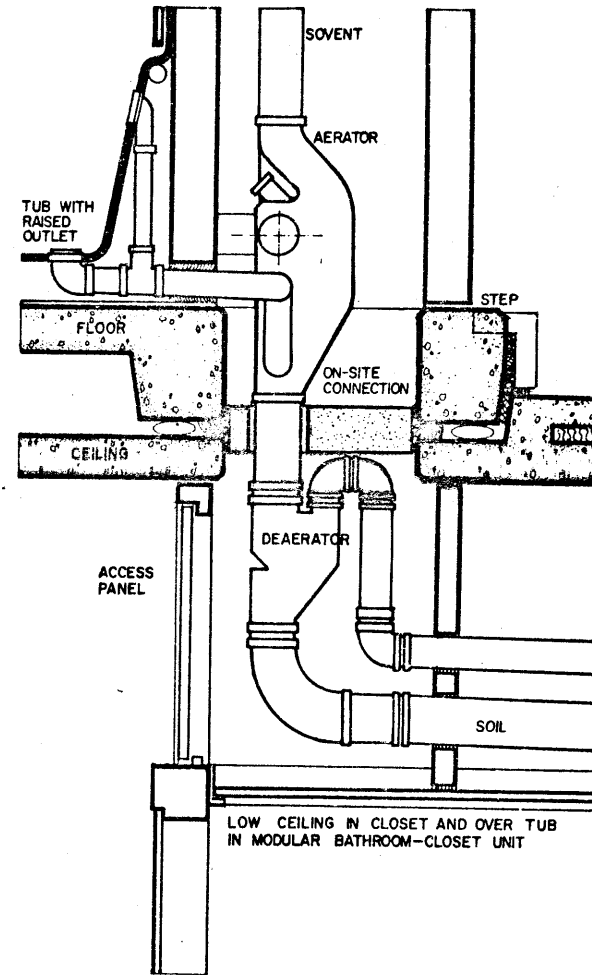
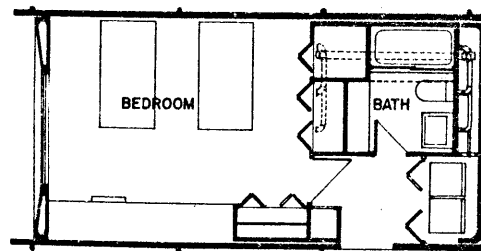
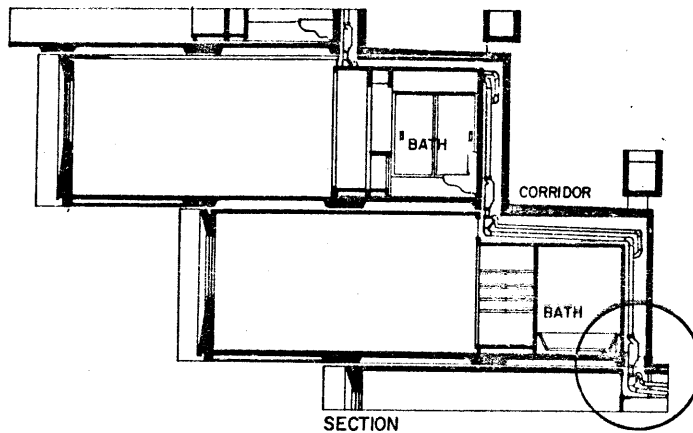


BOX-UNIT WITH TWO BEDROOMS
13'-0" x 40'-0"

OFFSET OPTION 1

Offsetting identical box-units (as shown below) or changing bathroom locations which do not line up vertically is possible with the SOVENT SYSTEM.

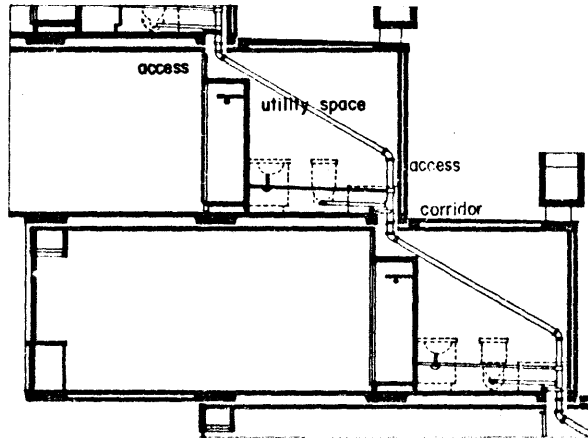
When the utility space is perpendicular to the side walls, offsets are achieved by running supply and waste pipes and ventilation tubing in the space (2'-6" x 1'-4" deep) built-in over the bathtub.



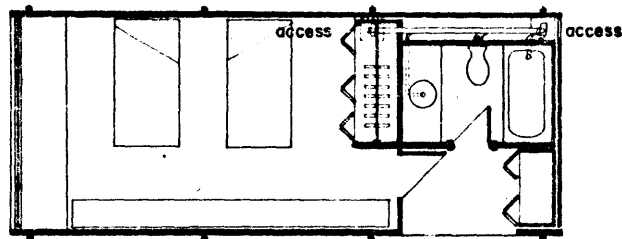
LOW CEILING IN CLOSET AND OVER TUB
IN MODULAR BATHROOM-CLOSET UNIT

OFFSET OPTION 2

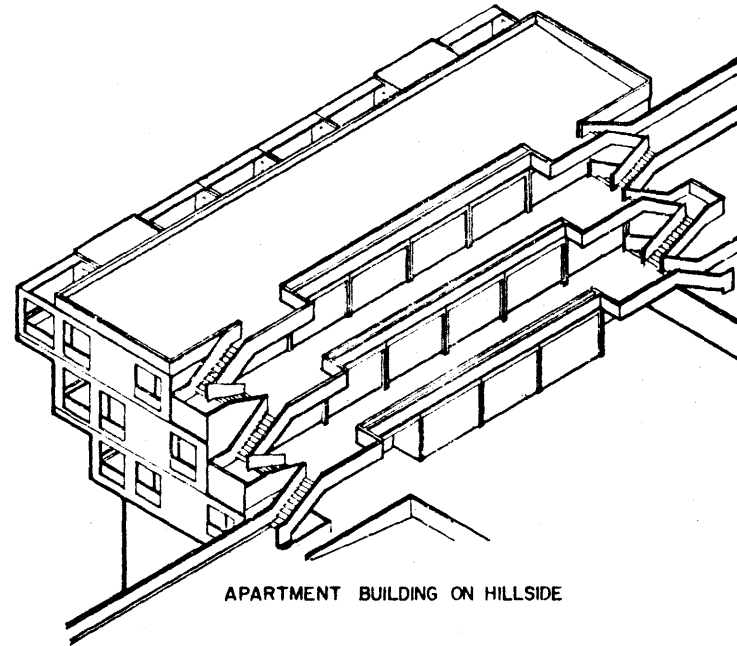
No deaerator fitting is required if the pipes slope 30° or more as is possible with the utility space parallel to the side walls.



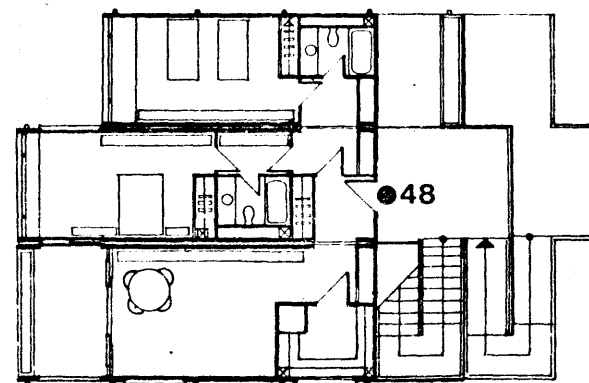
SECTION THROUGH UTILITY SPACE
(For clarity, only waste pipes are shown)



PLAN OF BEDROOM AND BATHROOM BOX-UNIT
10'-10" x 28'-2"

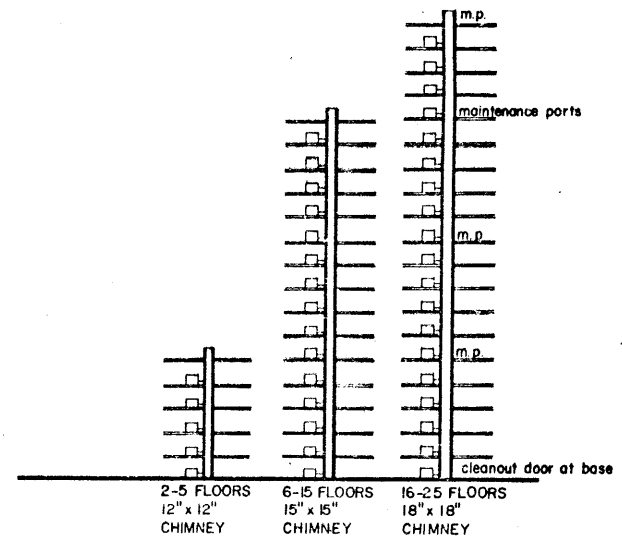
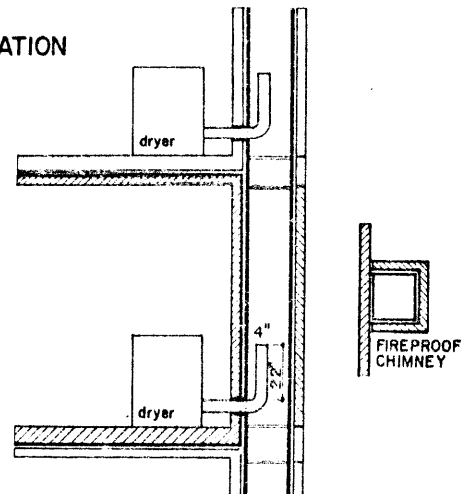


APARTMENT BUILDING ON HILLSIDE

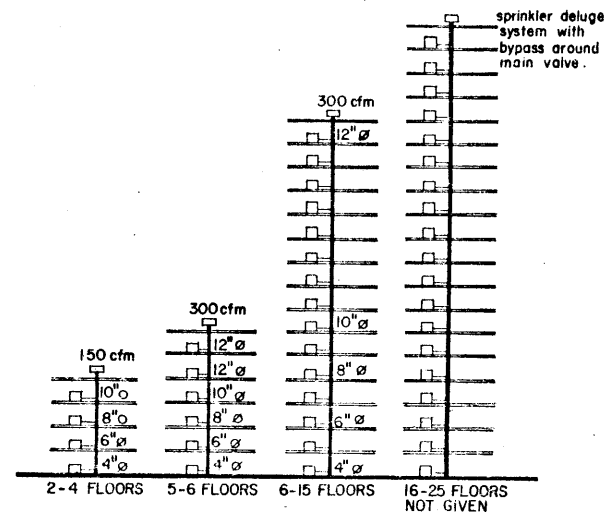
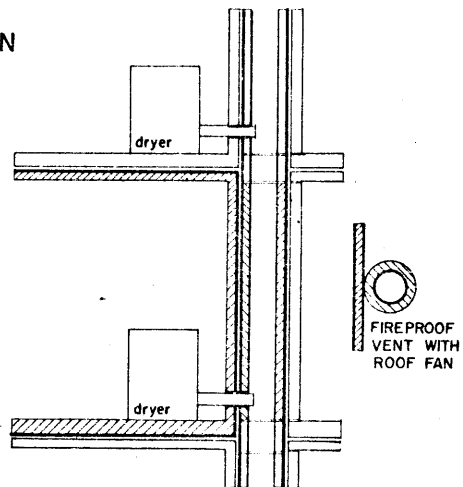


PLAN OF END APARTMENT

**SCHEME I
NATURAL CHIMNEY VENTILATION**



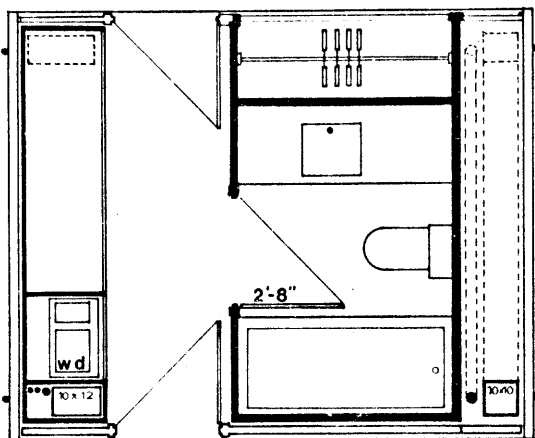
**SCHEME II
VENTING WITH EXHAUST FAN**



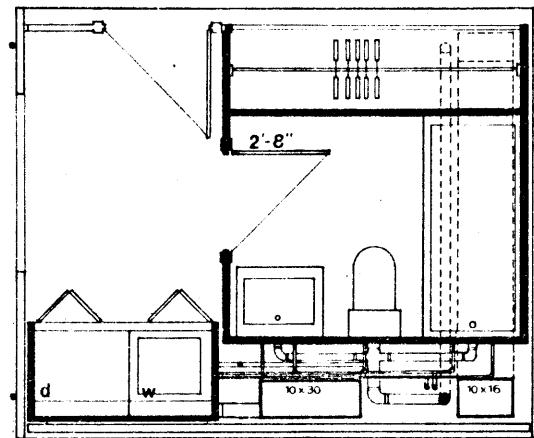
CHIMNEY SIZE REQUIREMENTS FOR DRYERS INSIDE APARTMENTS

Source MAYTAG ARCHITECTURAL GUIDE 1973 MAYTAG COMPANY NEWTON, IOWA

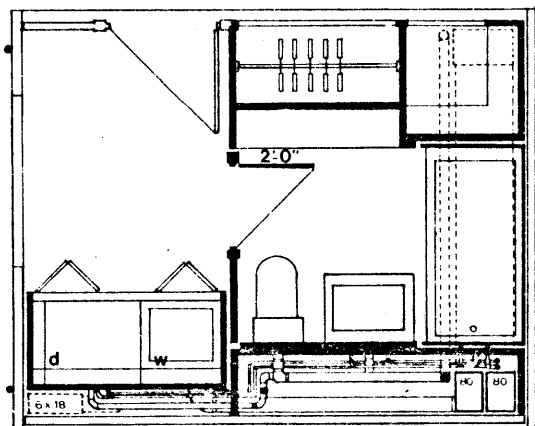
Adapted with permission of
the Maytag Company



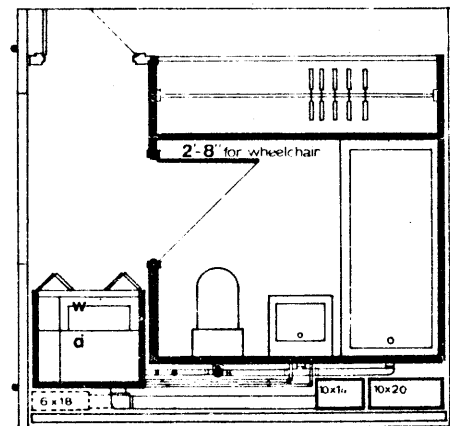
OFFSET OPTION



OFFSET OPTION



OFFSET OPTION WITH DRYER



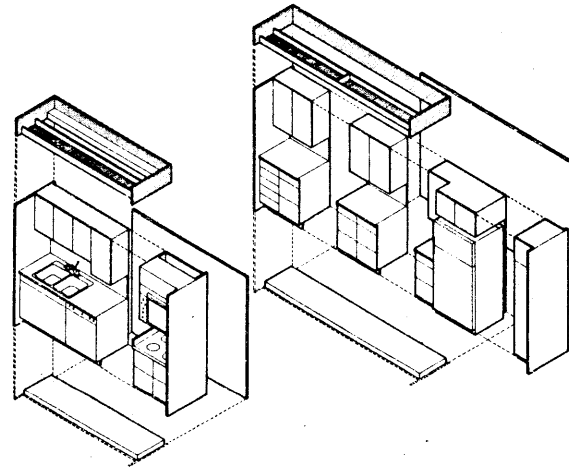
VERTICAL ONLY

LAUNDRY — BATHROOM COMBINATIONS SPECIAL CASES

KITCHENS

Kitchens have a supporting platform under the cabinets which serve as toe space; back walls serve as additional bracing. The kitchen modules can be supplied by an independent manufacturer or assembled from components at the factory. L-shaped units cannot be sent as a unit. They will be fabricated in two sections.

Hot and cold water supply pipes and waste pipes have relatively small diameters and are easily accommodated in vertical shafts and dropped ceilings (6 inches is sufficient). Vents can utilize the same type of flexible tubing now used in flexible hot-air systems. When the kitchen adjoins the corridor wall, there is the option to vent through the hung ceiling in the corridor.



An example of kitchen modules offered by DESCON/CONCORDIA SYSTEMS, LTD. in its concrete-panel system. This type of kitchen module is offered by many manufacturers for all types of construction.

DOORS

Various modular doors, complete with hardware and locks, come mounted in frames with gaskets for easy installation between other components.

A special entry door includes hardware, communications equipment, side panels, mail delivery slots, electric light for both public corridor and apartment entrance, and space for a vertical electrical conduit riser and circuit box on one side in the corner of the box.

Sliding doors and special doors between modules can be placed within a module and installed on site to eliminate joint irregularities.

CLOSETS

Closets are pre-assembled, including interior lighting and wiring--one panel for telephone, television, and electric outlets and wall switches. The electrical connection is made where the closet abuts the beam on one side of the module.

FLOORING

Hardwood flooring is preferred: blocks or tiles. Other options: vinyl tile and carpeting.

The bathroom floor is a one-piece pretiled panel or synthetic material panel (such as Coriam).

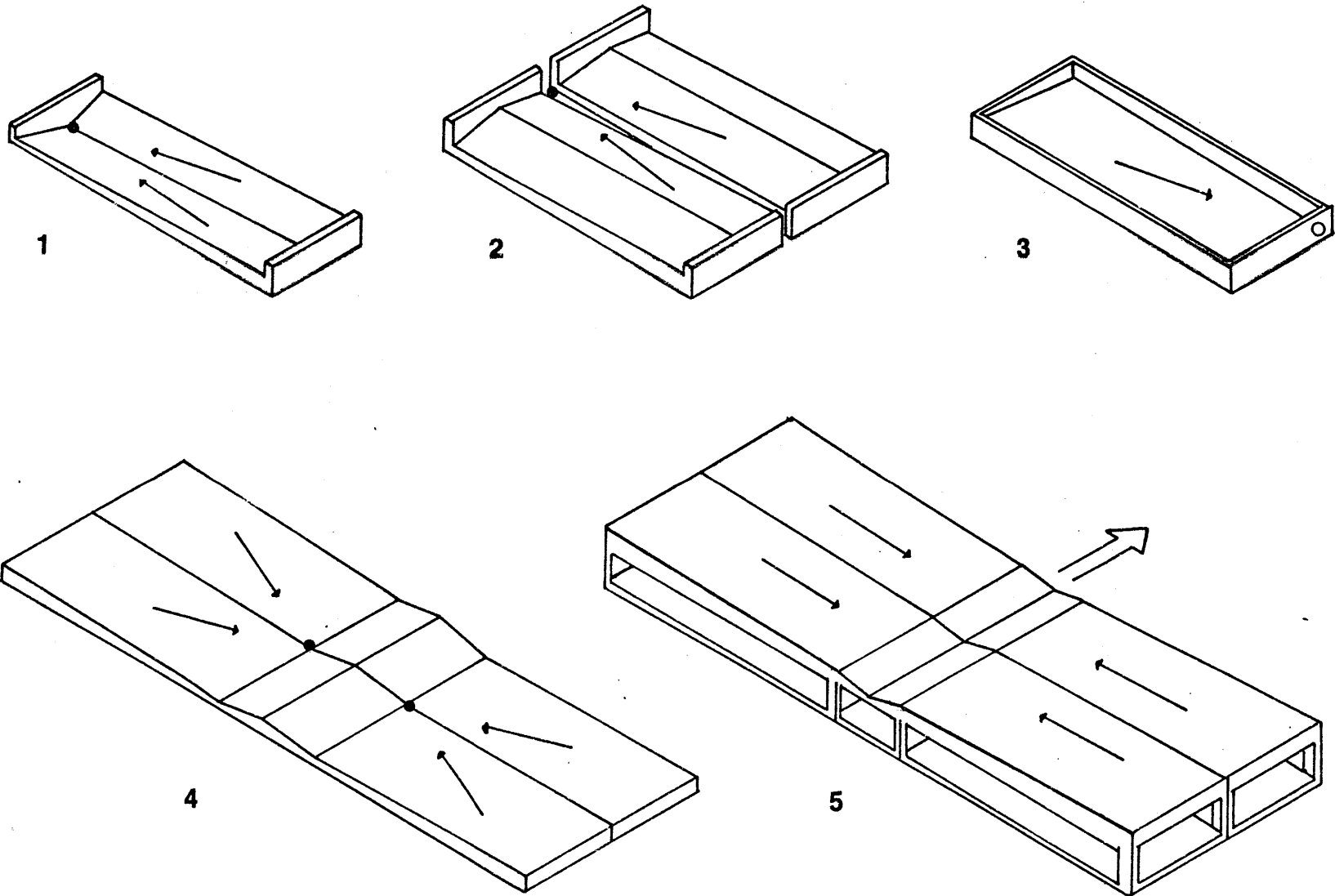
Experience will show if paper or plastic protection for floors is necessary for transit and finishing work done on site.

The floor slab has a very smooth surface so most flooring can be applied directly,

SURFACES

Surfaces will be prepared to eliminate imperfections. The preferred ceiling is vermiculite plaster for its ability to absorb moisture. Other options: paint, textured or acoustical.

Walls can be painted, papered, or paneled.



ROOF DRAINAGE

The type of roof will depend on the building application. Single-family dwellings and townhouses could rely on simple pitched roofs and gutters. High-rise buildings, especially with penthouses, would require on-site roofing applications. Mansard roofs, solar collectors, etc. would also be possible, not to mention sod roofs and dirt terraces.

Basic drainage methods are shown on the opposite page.

- 1 Drainage can occur inside the box-unit--connecting to a mechanical shaft such as in the bathroom or brought into the corner with a flexible pipe. The scale of the drawing is exaggerated for clarity.
- 2 Drainage between box-units either at the facade or at the junction with the corridor.
- 3 Drainage outside the box-unit with a water-spout.

- 4 The uppermost box-units can be provided with slabs which incline inward to corridor drains or outward to gutters.

Alternately, the roofing material can be fabricated or assembled to produce the necessary slope.

Some roofs, especially in very hot climates are designed to contain a specific water level for 'natural' cooling. [32]

- 5 Prefabricated roof sections for standard-type buildings contain all the mechanical ductwork and pipes, wiring, etc. for horizontal distribution. Gutters could be incorporated at the perimeter, or a trough, as shown, could be devised.

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AND CONSTRAINTS
Cornell University Press, 1971
- #2 A. Herrey and W. Litle
INDUSTRIALIZED HOUSING FEASIBILITY
STUDY, M.I.T. Press, Cambridge, 1971
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COST ESTIMATING IN INDUSTRIALIZED
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- #4 FEEDBACK: 22 Housing Systems for
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TIME-SAVER STANDARDS FOR ARCHITECTURAL
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(b)FOR BUILDING TYPES
- #10 APARTMENT CONSTRUCTION NEWS Magazine
Gralla Publications, New York, N.Y.
- #11 COMPONENTS, INC. 4400 Homerlee,
East Chicago, Ind. 46312 Brochure
- #12 SMITH NO-HUB DRAINAGE CATALOG #NH-2
Piscataway, New Jersey 08854
- #13 COMBI-CORE CORP., Jackson, Miss.
- #14 DESCON/CONCORDIA SYSTEMS, LTD.
Montreal, Canada
- #15 ALCOA CONSTRUCTION SYSTEMS
576 L Alcoa Bldg. Pittsburgh, Pa. 15219
- #16 AMERICAN SOCIETY OF MECHANICAL ENGINEERS
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- #17 STREIF SANITARBAU, D-6483 Salmünster 1
Hanauer Landstr.4, W. Germany
- #18 Copper Development Assoc., Inc; New York, N.Y.
DESIGN HANDBOOK: Single-Stack Plumbing System
- #19 H.R.Hay and J.I. Yellott
CONSTRUCTION AND OPERATION OF A NATURALLY
AIR-CONDITIONED BUILDING.
Sky Therm Processes and Engineering,
Phoenix, Arizona, 1968
- #20 EDWARDS ENGINEERING CORP.
101 Alexander Avenue
Pompton Plains, New Jersey 07444

FOOTNOTES

- | | | | |
|----|---------------------|----|------------------|
| 1 | Source #1 p. 68 | 27 | Ibid. |
| 2 | Source #2 p. 415+ | 28 | Source #6 p. 11 |
| 3 | Source #2 p. 88+ | | Aug. 29, 1974 |
| 4 | Source #3 | 29 | Ibid. |
| 5 | Source #4 | 30 | Source #8 p. 66+ |
| 6 | Source #5 | | Also, Source #18 |
| 7 | Source #6 p. 22 | 31 | Source #18 |
| | Aug. 29, 1974 | 32 | Source #19 |
| 8 | Source #7 | | |
| 9 | Source #8 p.328 | | |
| 10 | Source #9 p.840 | | |
| 11 | Ibid. | | |
| 12 | Source #20 | | |
| 13 | Source #8 p.321 | | |
| 14 | Source #10 p. 70 | | |
| | November, 1974 | | |
| 15 | Ibid. | | |
| 16 | Ibid. | | |
| 17 | Source #9 p. | | |
| 18 | Source #9 p.840 | | |
| | DESIGN DATA | | |
| 19 | Source #12 | | |
| 20 | Source #15 | | |
| 21 | Source #11 | | |
| 22 | Source #17 | | |
| 23 | Source #14 | | |
| 24 | Source #13 | | |
| | Also, Professional | | |
| | Builder Magazine | | |
| | IB Feb., 1974 p.145 | | |
| 25 | Source #4 | | |
| 26 | Source #7 | | |

IX. Apartment and Building Types

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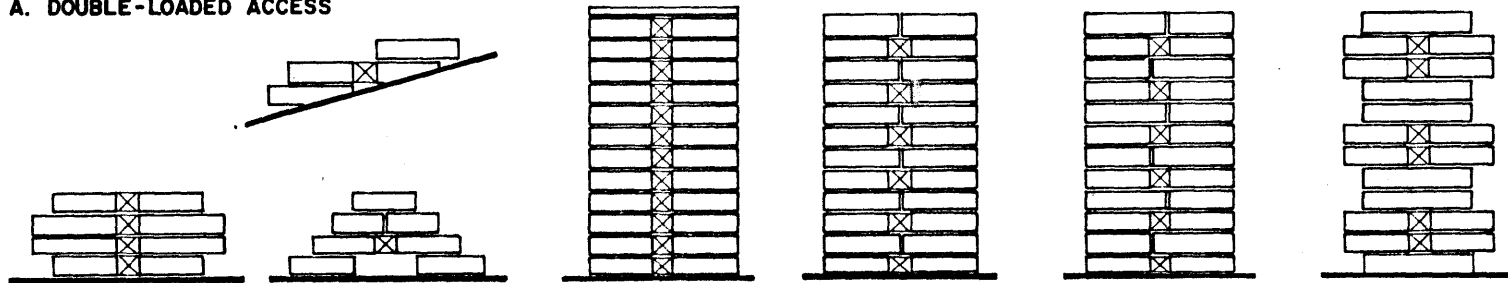
Introduction

This chapter presents the wide range of apartment and building types possible using the proposed "Offset" System.

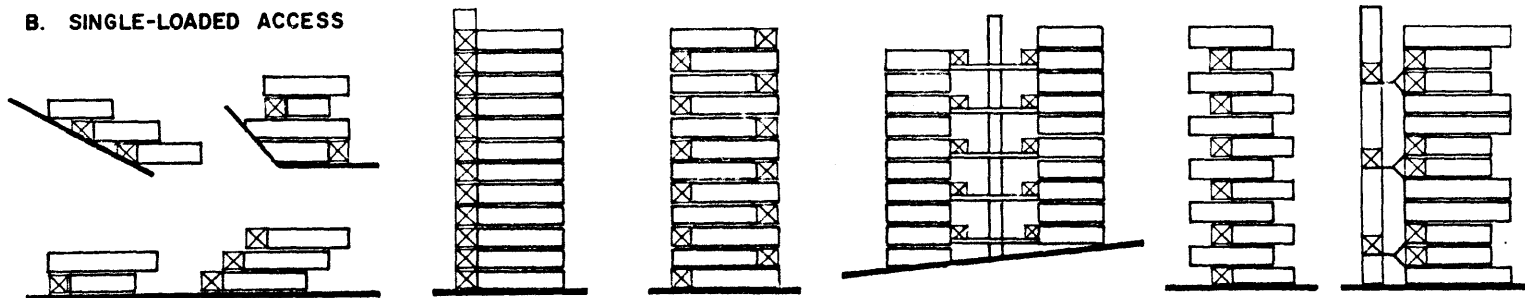
Some of the plans are well developed but others are in the schematic stage. Nevertheless, the principles of application are apparent.

Although the system shown would probably be most successful for multi-family complexes, there is no reason why some adaptations could be made to suit the single-family market. Single family types are not shown, but many of the 'apartment' types are essentially adaptable for use.

A. DOUBLE-LOADED ACCESS

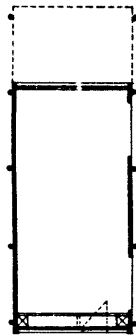


B. SINGLE-LOADED ACCESS

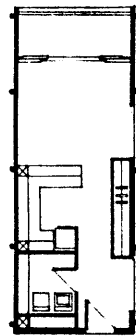




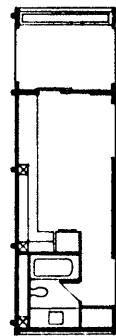
BOX UNITS WITH UTILITY OPENINGS AT 8'-8" INTERVALS



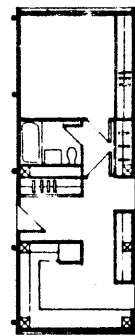
BOX 15
13'-0" x 28'-2"



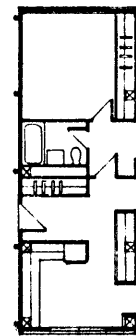
BOX 16
13'-0" x 36'-10"



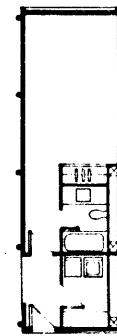
BOX 17
10'-10" x 36'-10"



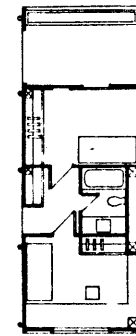
BOX 18
13'-0" x 36'-10"



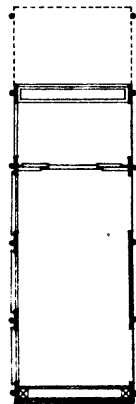
BOX 19
13'-0" x 36'-10"



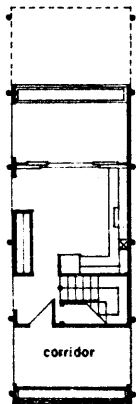
BOX 20
10'-10" x 36'-10"



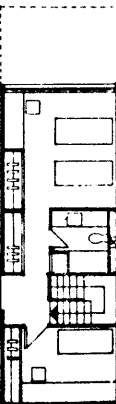
BOX 21
13'-0" x 36'-10"



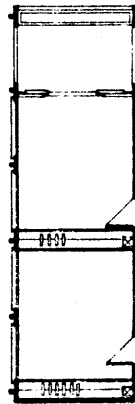
BOX 22
13'-0" x 36'-10"



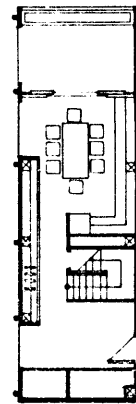
BOX 23
13'-0" x 36'-10"



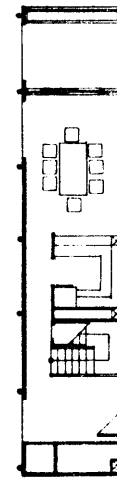
BOX 24
13'-0" x 36'-10"



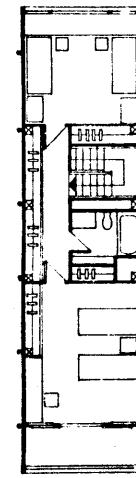
BOX 25
13'-0" x 45'-6"



BOX 26
13'-0" x 45'-6"

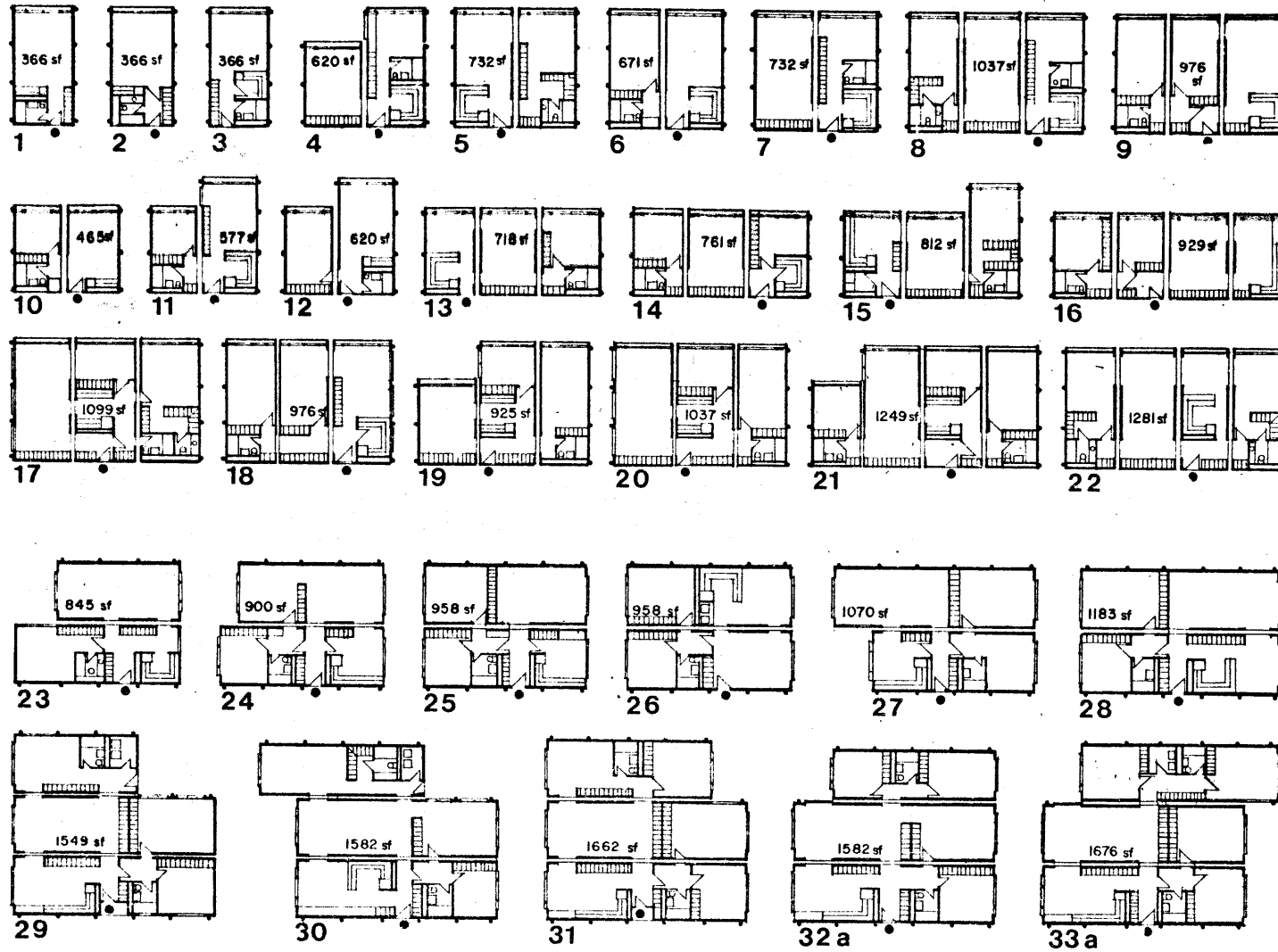


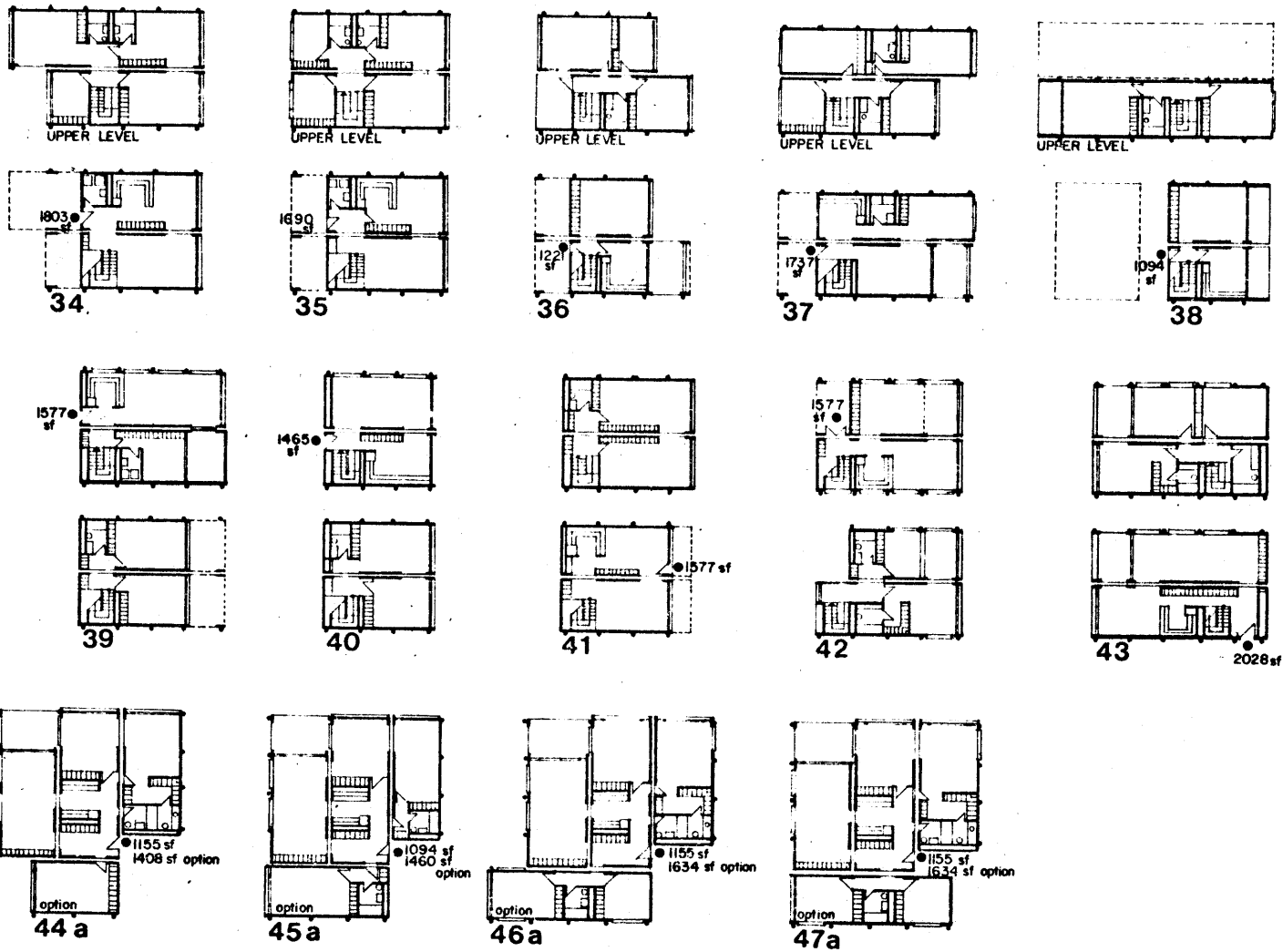
BOX 27
10'-10" x 54'-2"



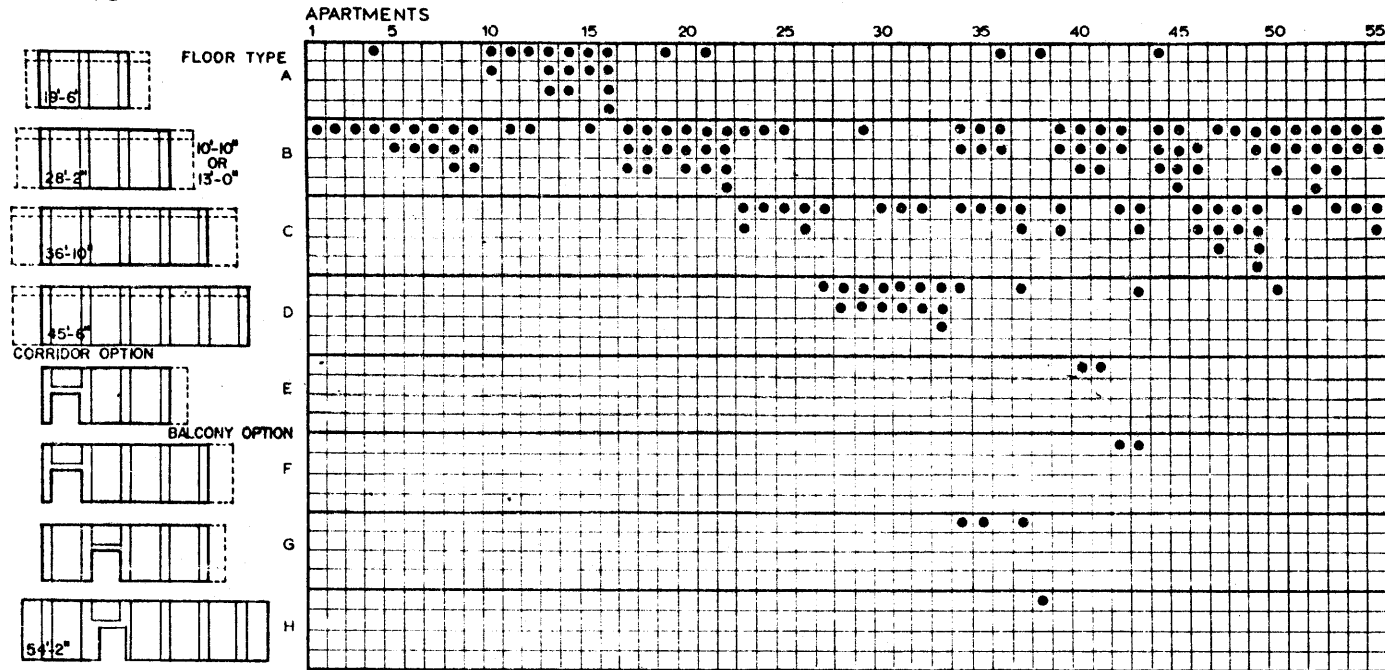
BOX 28
13'-0" x 54'-2"

Apartments



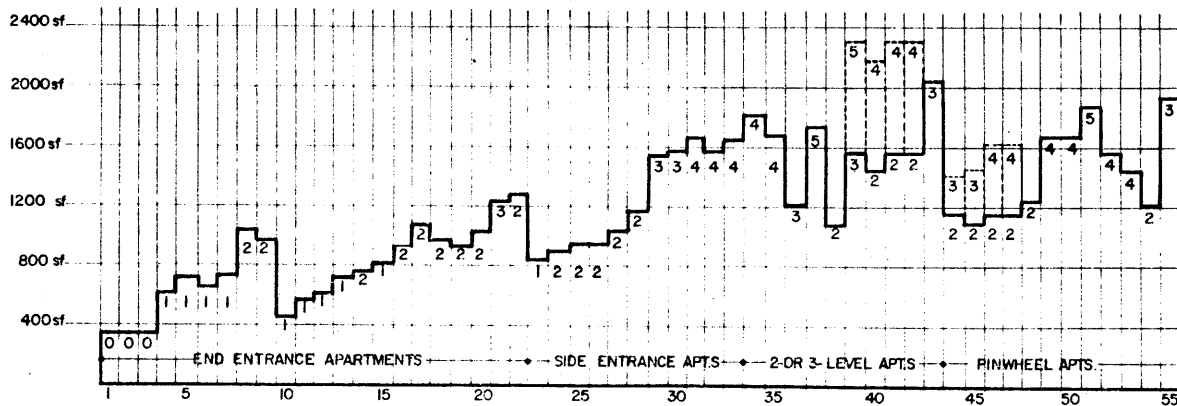


FLOORS



APARTMENT AREAS

NUMBERS INDICATE
NUMBER OF BEDROOMS



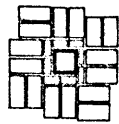
The chart on the opposite page shows the frequency of use of five basic floor lengths. Corridor and balcony options are not included--their use would depend on optional requirements. The dashed line indicates the extent of balconies or corridors for each floor slab.

In order to provide apartment area flexibility, two different box widths are recommended: 13'-0" and 10'-0". An eleven foot wide slab could be used instead of the 'modular' width.

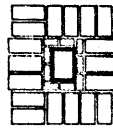
Apartment areas are calculated to show the range possible using the basic floor slabs shown above. Numbers indicate the number of bedrooms for each dwelling.

BUILDING TYPES

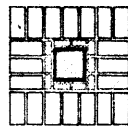
TOWER BUILDINGS



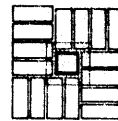
TOWER 1



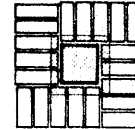
TOWER 2



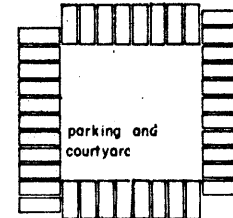
TOWER 3



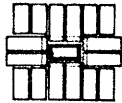
Variation of
Tower 1



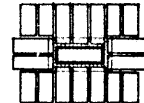
TOWER 7



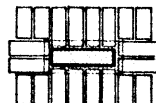
TOWER 8
Low rise or pyramid options



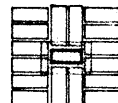
TOWER 4



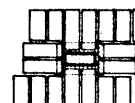
TOWER 5



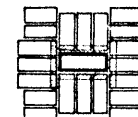
TOWER 6



Variation of
Tower 4

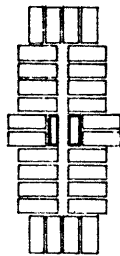


Variation of
Tower 5

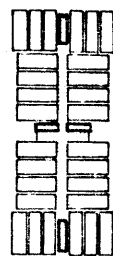


Variation of
Tower 5

DOUBLE-LOADED-CORRIDOR BUILDINGS



D.L.C. 1



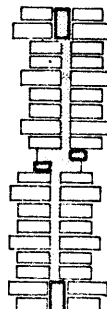
D.L.C. 2



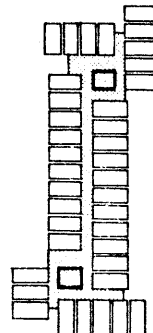
D.L.C. 3



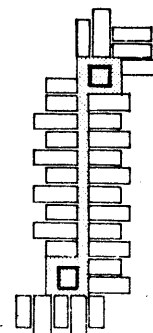
D.L.C. 4



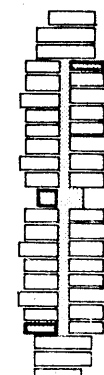
D.L.C. 5



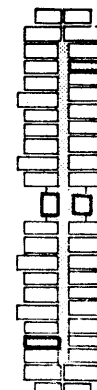
D.L.C. 6



D.L.C. 7



D.L.C. 8



D.L.C. 9

The great majority of high-rise apartment buildings will be either TOWERS or DOUBLE-LOADED-CORRIDOR buildings in their basic form.

TOWERS are categorized by the shape and dimensions of the core area. For example, Tower 1 has a central core containing elevator, stair, and vertical services with a dimension about 1.5 x 1.5 box-unit widths.

Tower 1: 1.5 x 1.5
Tower 2: 1.5 x 2.0
Tower 3: 2.0 x 2.0
Tower 4: 1.0 x 2.0
Tower 5: 1.0 x 3.0
Tower 6: 1.0 x 4.0
Tower 7: 2.5 x 2.5

Enlarged plans on pages 232 and 233 show that cores may be enlarged to the limits of the dotted lines. Maximum volumes for the seven tower types, and variations are shown abstractly on pages 230 and 231.

Using the OFFSET SYSTEM, buildings can attain a 'plastic' aspect with many protrusions, recesses, and convex or concave tendencies--but unless carefully studied, unwanted shadows could be cast upon the neighbors or views opened to rooms nearby.

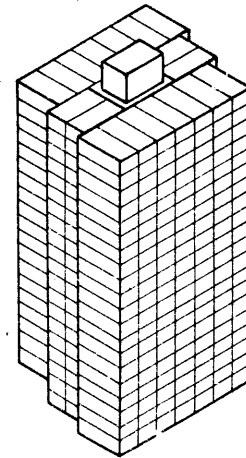
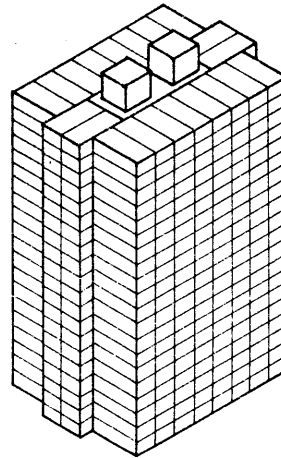
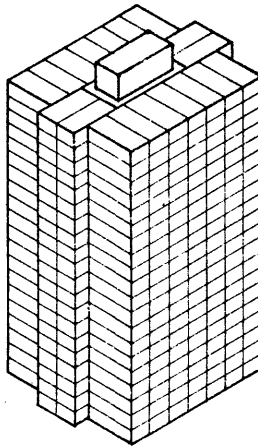
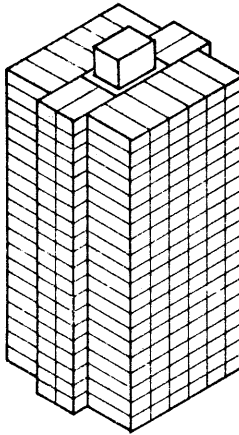
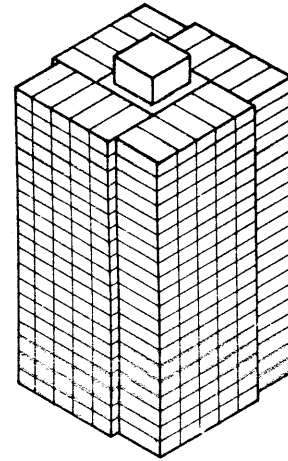
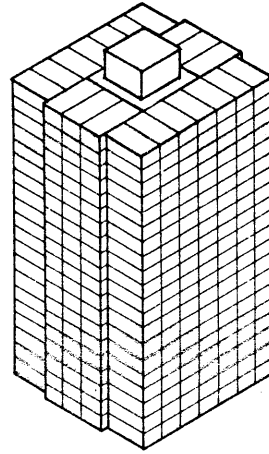
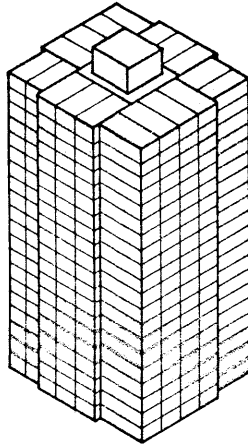
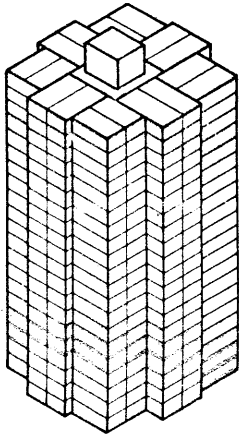
DOUBLE-LOADED-CORRIDOR buildings are categorized by the location of the elevator and stair cores. Nine basic types are shown.

The illustrations give the maximum length as determined by the 75 ft. (or other code dimension) from apt. door to the fire stair.

Of course, the basic types can be varied internally by interchangeable modular apartment types and externally by several means including:

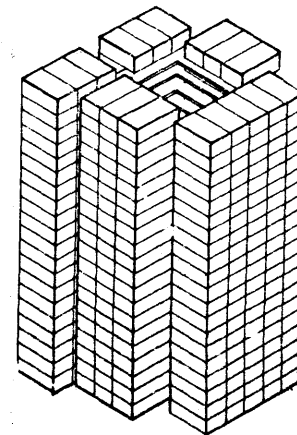
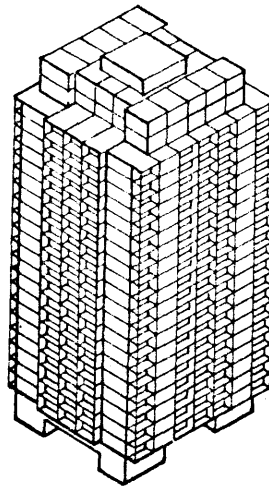
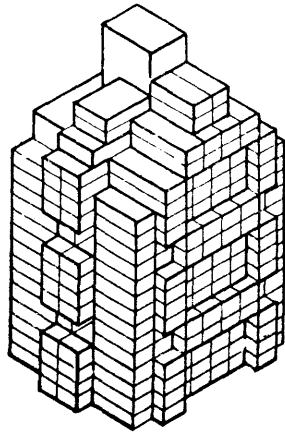
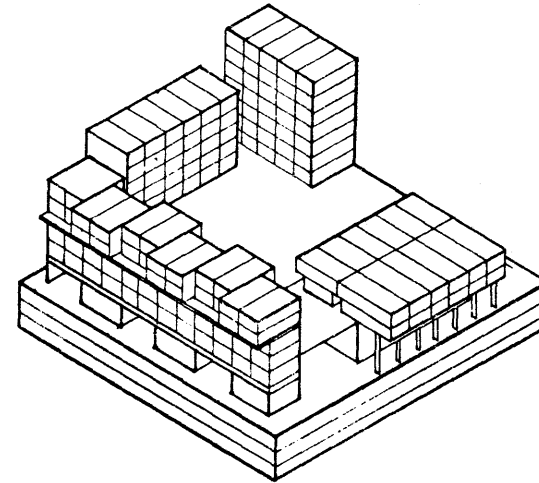
1. Reduction of height in segments or across an entire floor.
2. Shortening both halves or one half.
3. Forming clusters of low-rise buildings at the base, close-in or far away.
4. Providing a base: terrace, parking structure below or above ground.
5. Elevating the building on pilotis.
6. Creating voids by removing vertical or horizontal segments from the building.
7. Removing or recessing box-units.
8. Extending box-units or balconies.
9. Bridging one building to its site or to another building.
10. Creating patterns in the facade with materials, colors, textures, and patterns by window locations, etc.

TOWERS



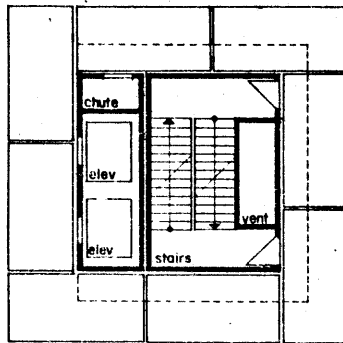
External variations are possible by

1. use of clusters at the base.
2. use of podium: shops, parking, recreation use.
3. removing or recessing box-units.
4. extending or recessing balconies.
5. extending box-units.
6. creating patterns by the location of the above elements, by change of window and facade treatments, colors, material, textures, etc.
7. opening segments of the tower along the lines of the corridors.
8. elevating the tower on pilotis.
9. height change.
10. bridging to other buildings or to the site.

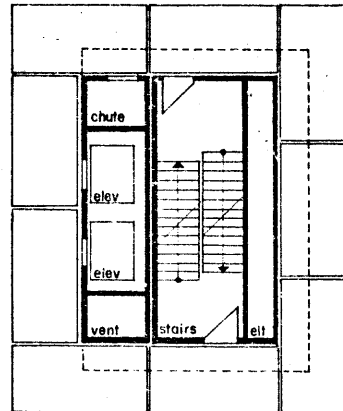


TOWER PLANS

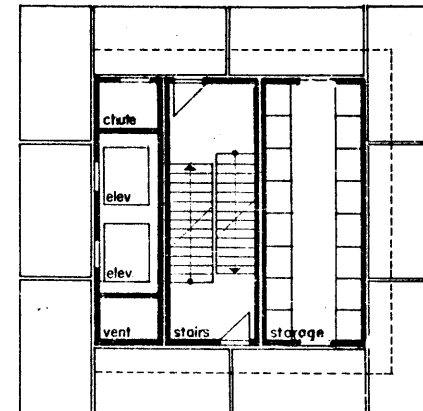
WITH CORRIDORS FORMED
WITH SEPARATE PANELS



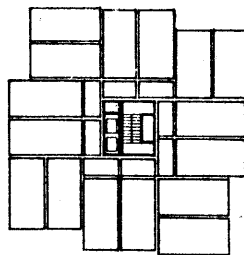
CIRCULATION CORE 1



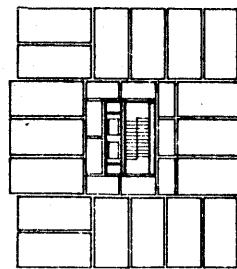
CORE 2



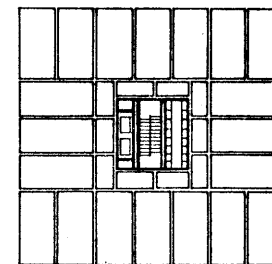
CORE 3



TOWER 1



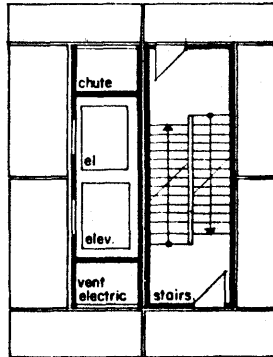
TOWER 2



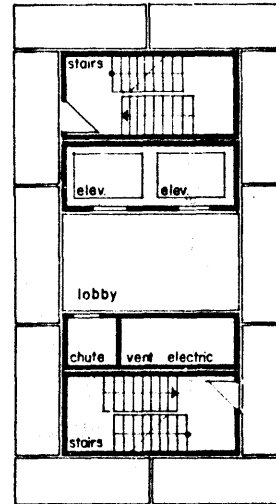
TOWER 3

TOWER PLANS

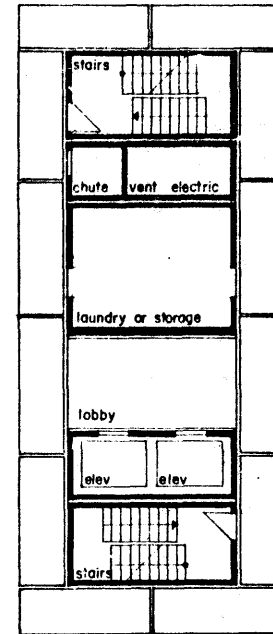
WITH CORRIDORS FORMED BY
CANTILEVERING FLOORS AT
END OF BOX UNITS OR WITH
SEPARATE PANELS



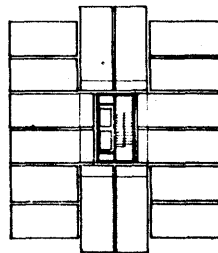
CORE 4



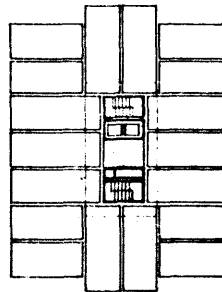
CORE 5



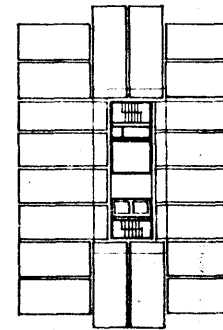
CORE 6



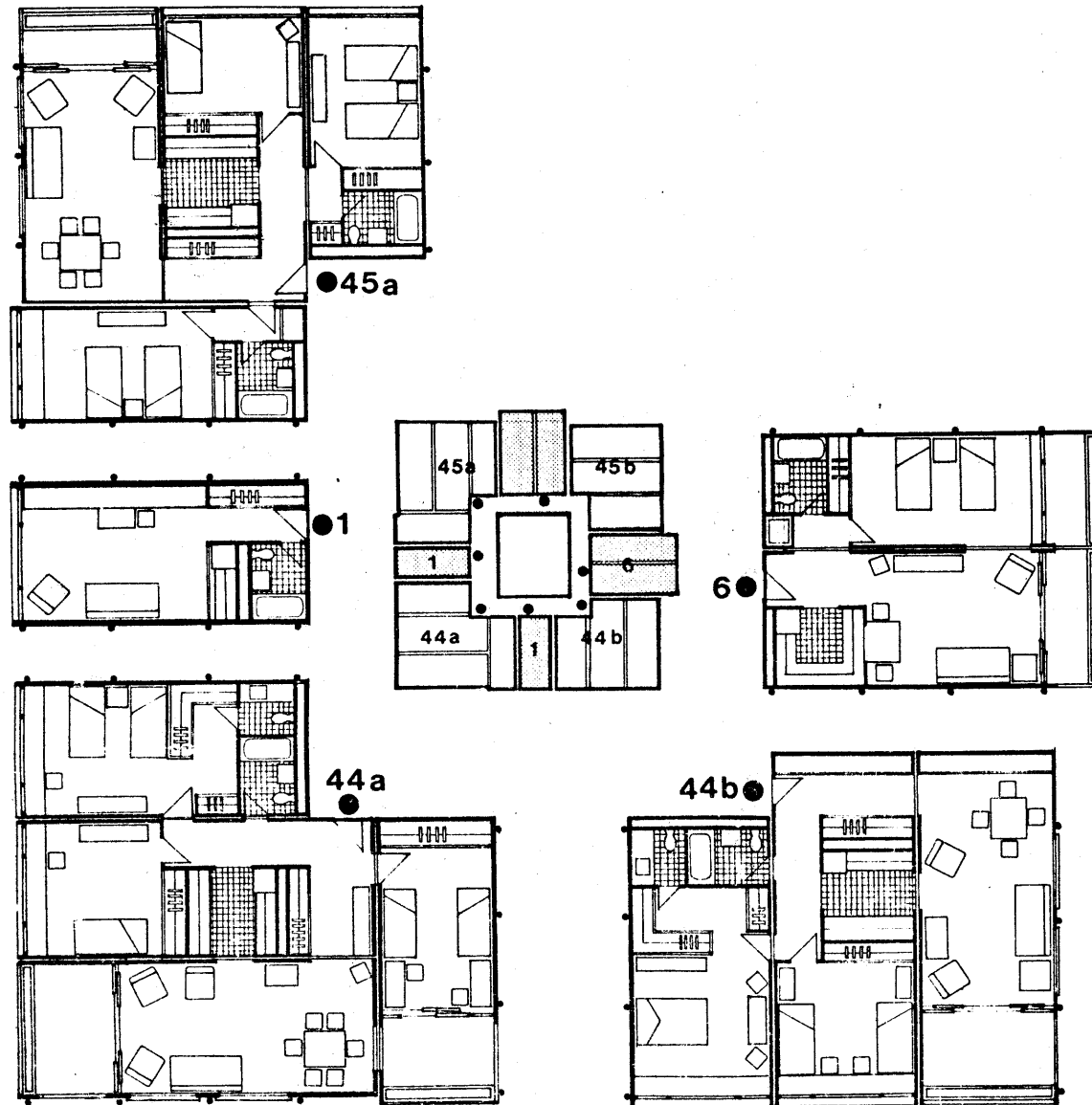
TOWER 4



TOWER 5

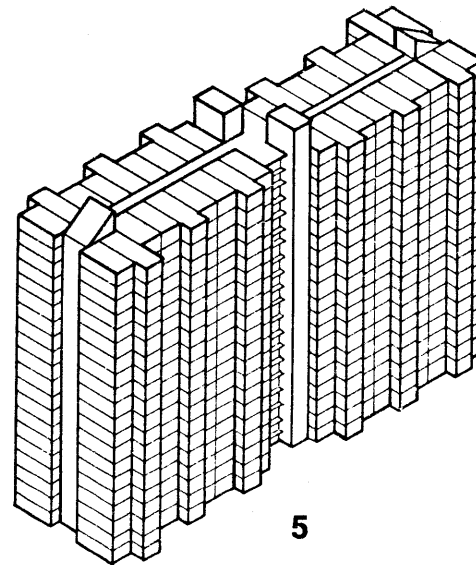
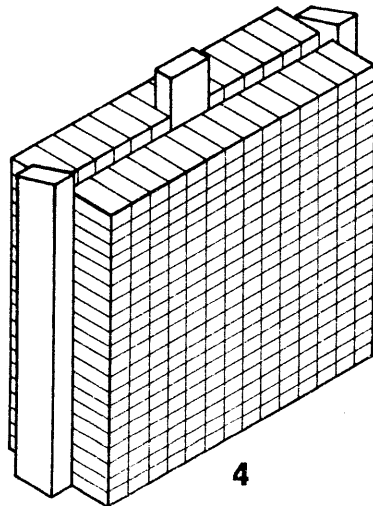
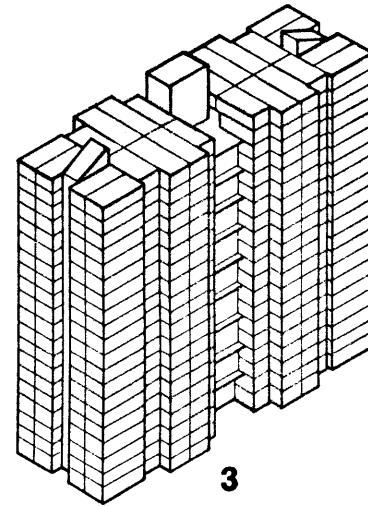
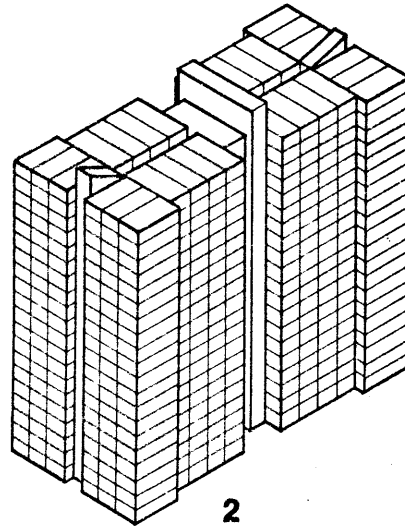
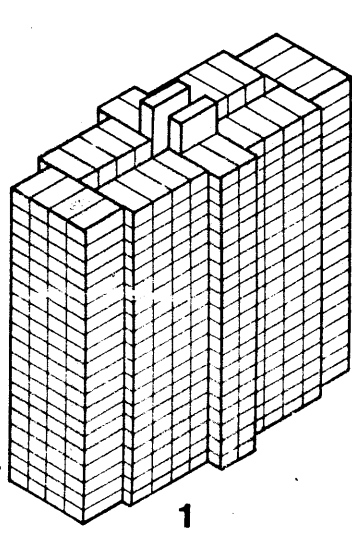


TOWER 6

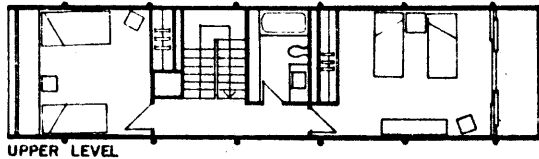




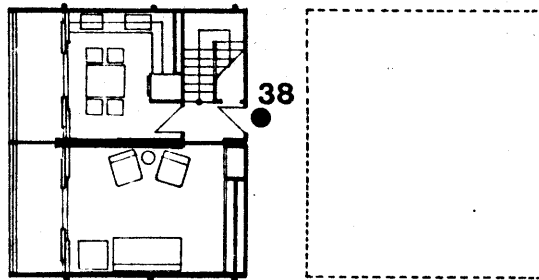
DOUBLE-LOADED CORRIDOR BUILDINGS



TWO LEVEL APARTMENTS WITH CROSS VENTILATION



UPPER LEVEL



LOWER LEVEL
2-BEDROOM APT. 38
1094 SF

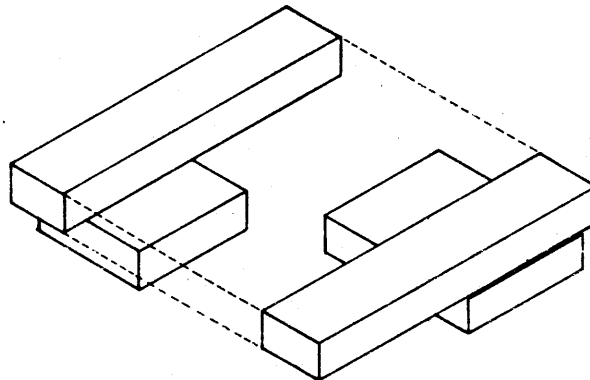
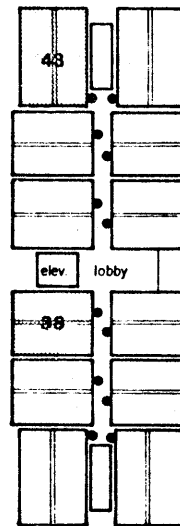
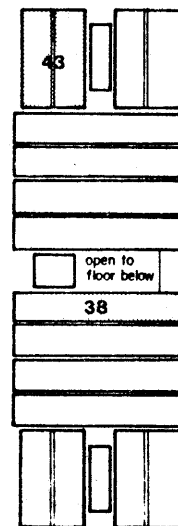


DIAGRAM SHOWING TWO APARTMENTS (TYPE 38) OVERLAPPING
ON TWO LEVELS TO PROVIDE CROSS-VENTILATION

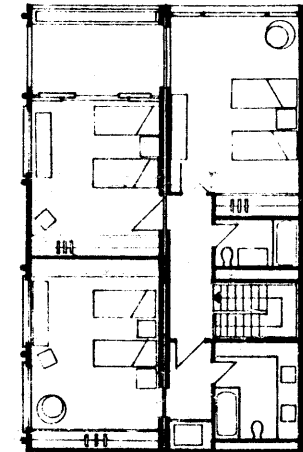


LOWER LEVEL
WITH CORRIDOR

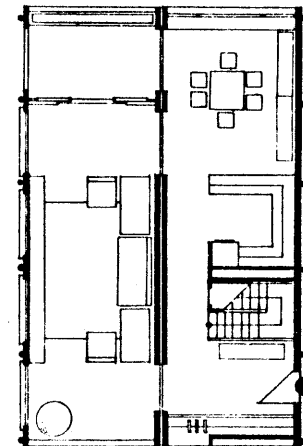
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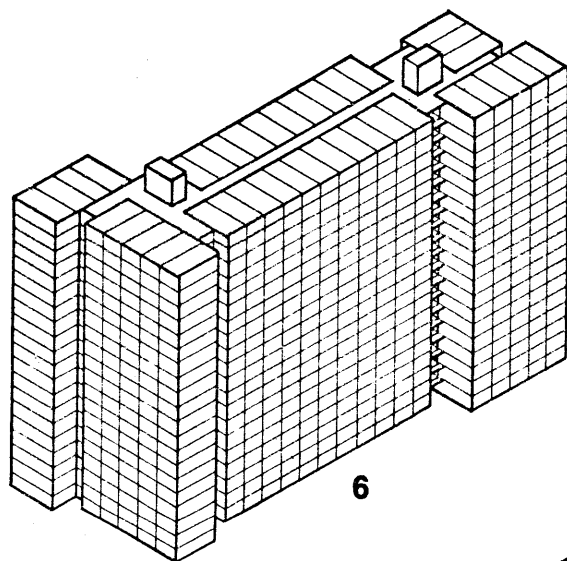
UPPER LEVEL



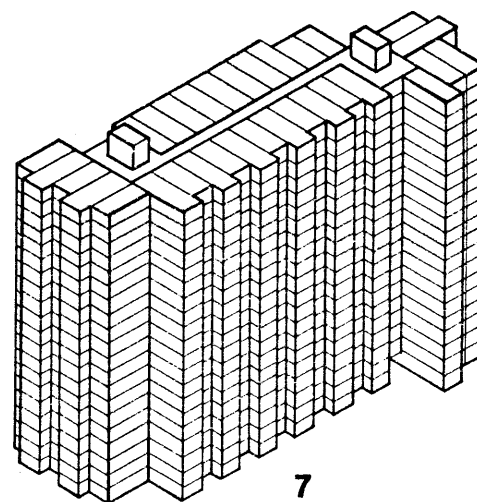
UPPER LEVEL APT. 43



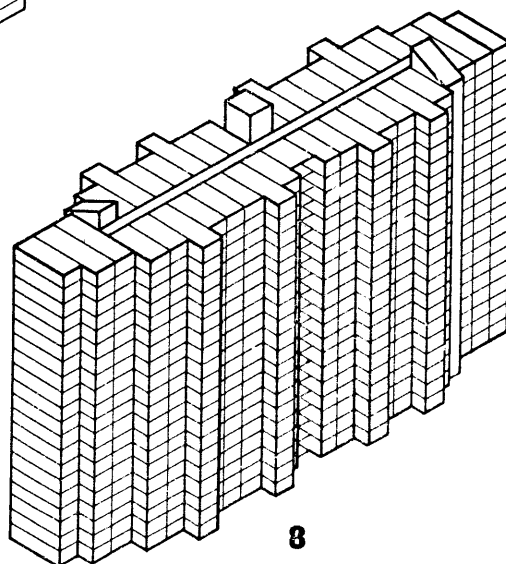
LOWER LEVEL APT. 43
3-BEDROOM LUXURY END APARTMENT
2028 SF
(Also converts to duplex townhouse)



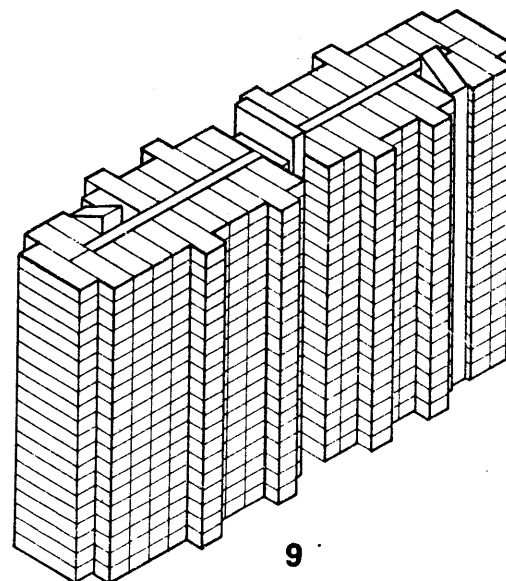
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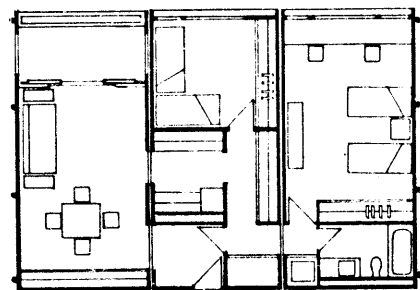
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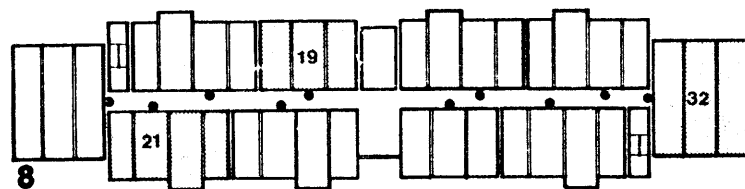
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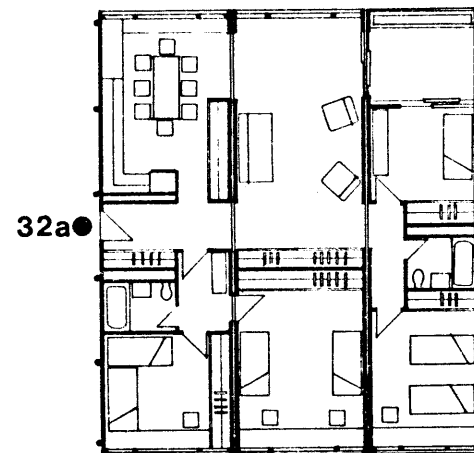
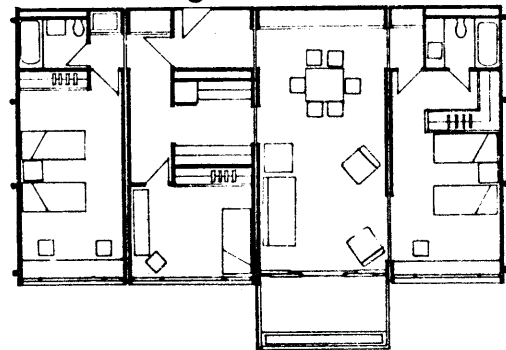
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19

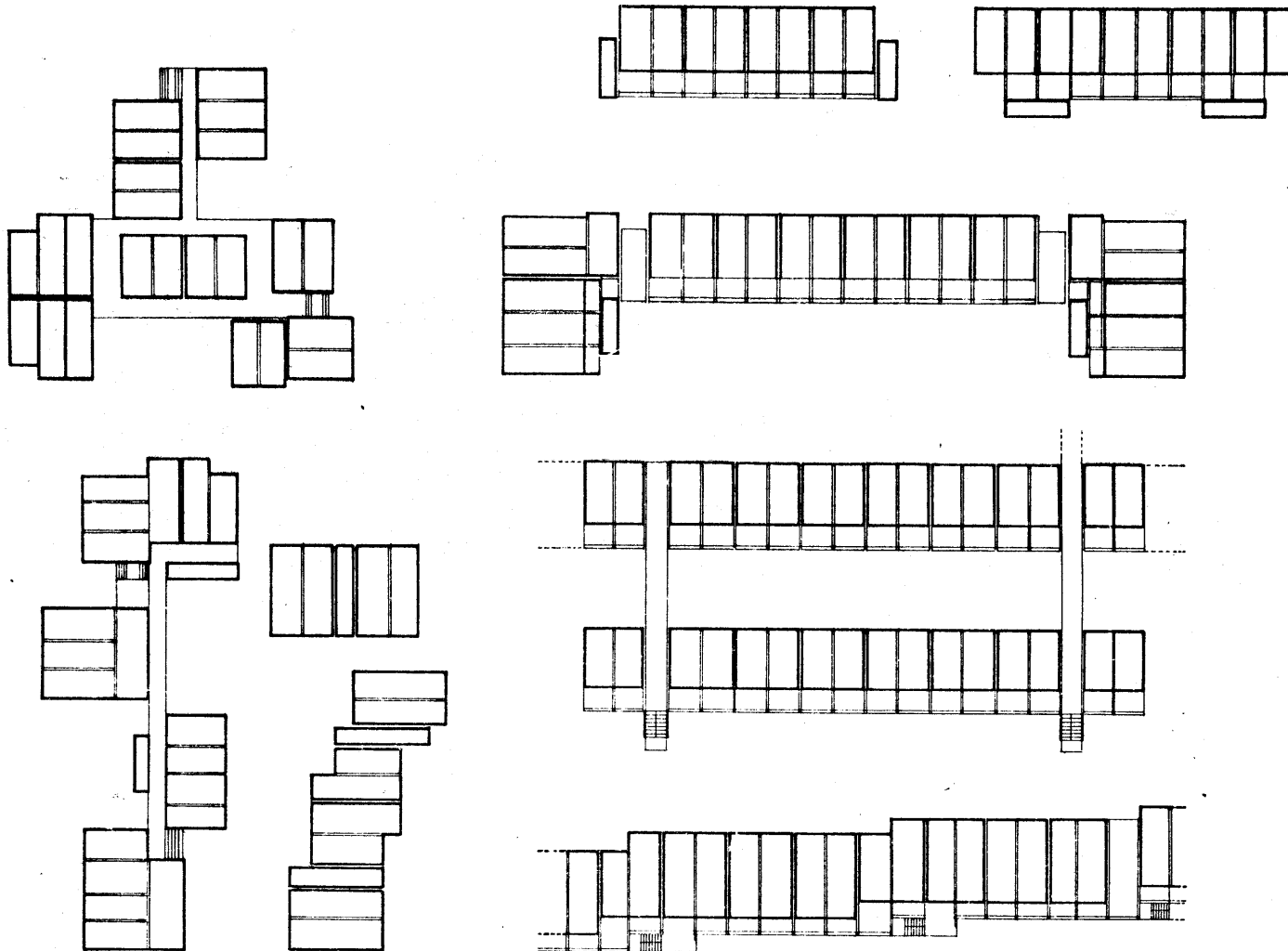


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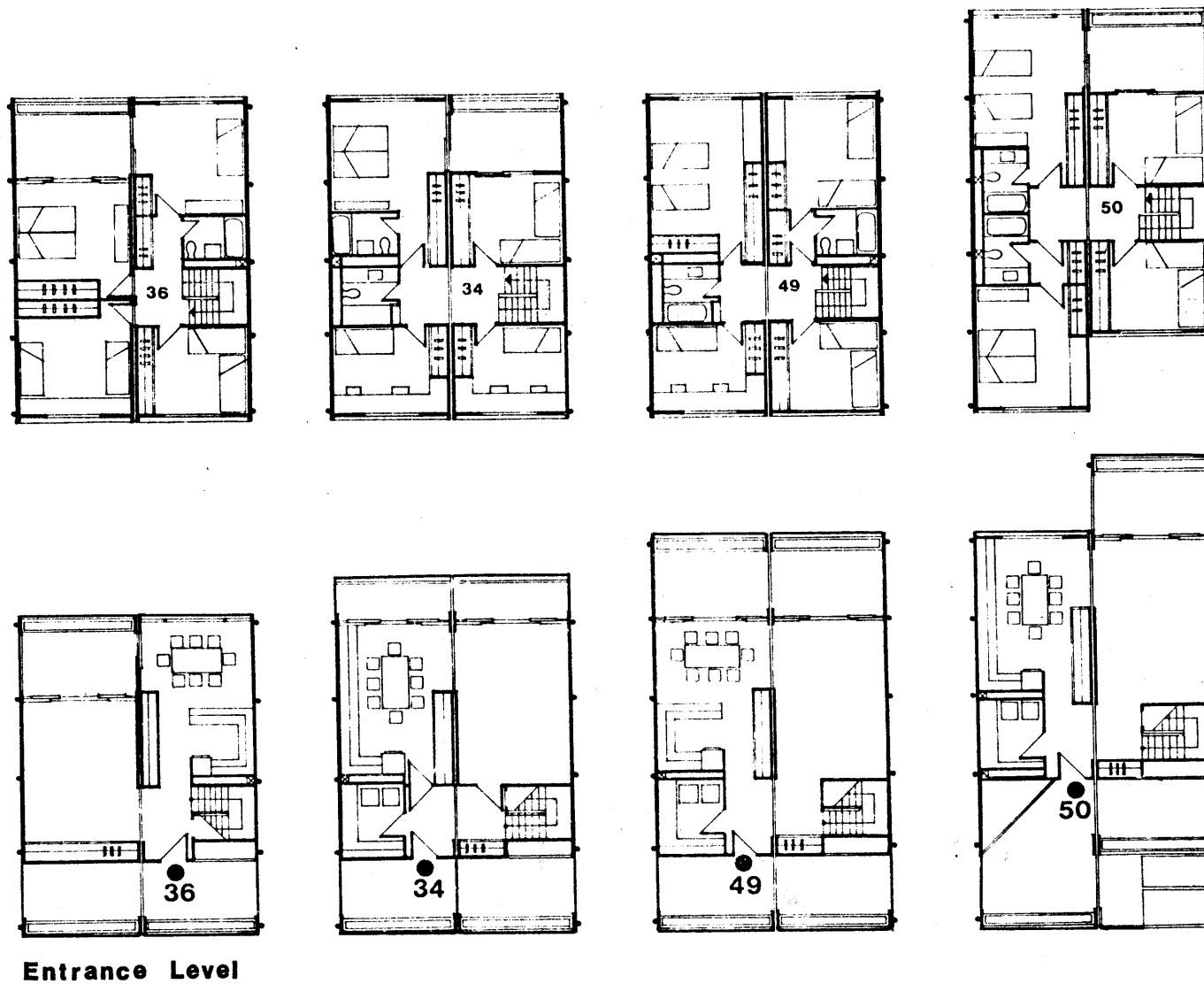


32a

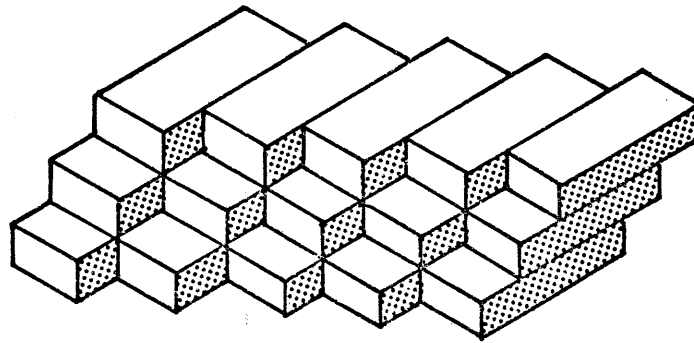
CLUSTER AND LINEAR GROUPINGS



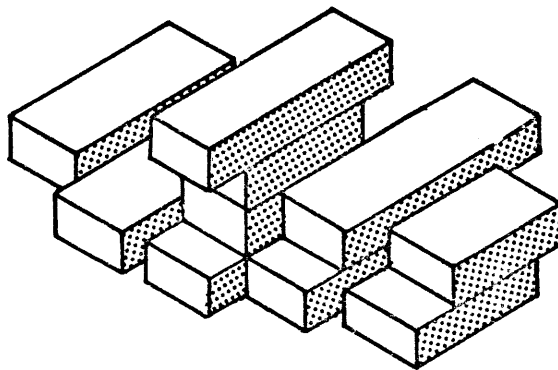
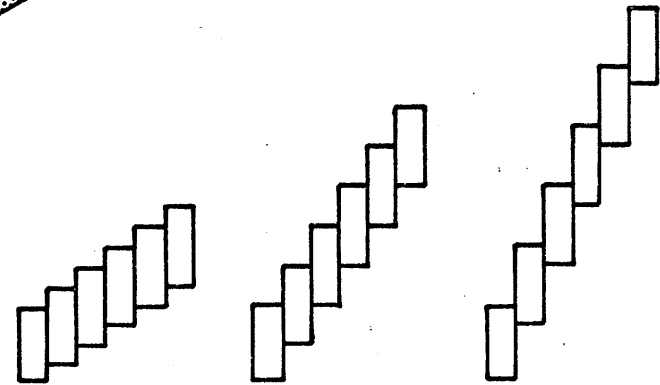
TWO-STORY DWELLINGS



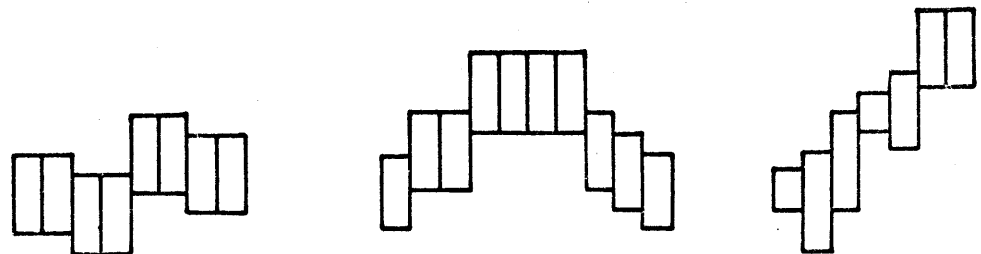
ABSTRACTIONS FOR LOW-RISE HOUSING

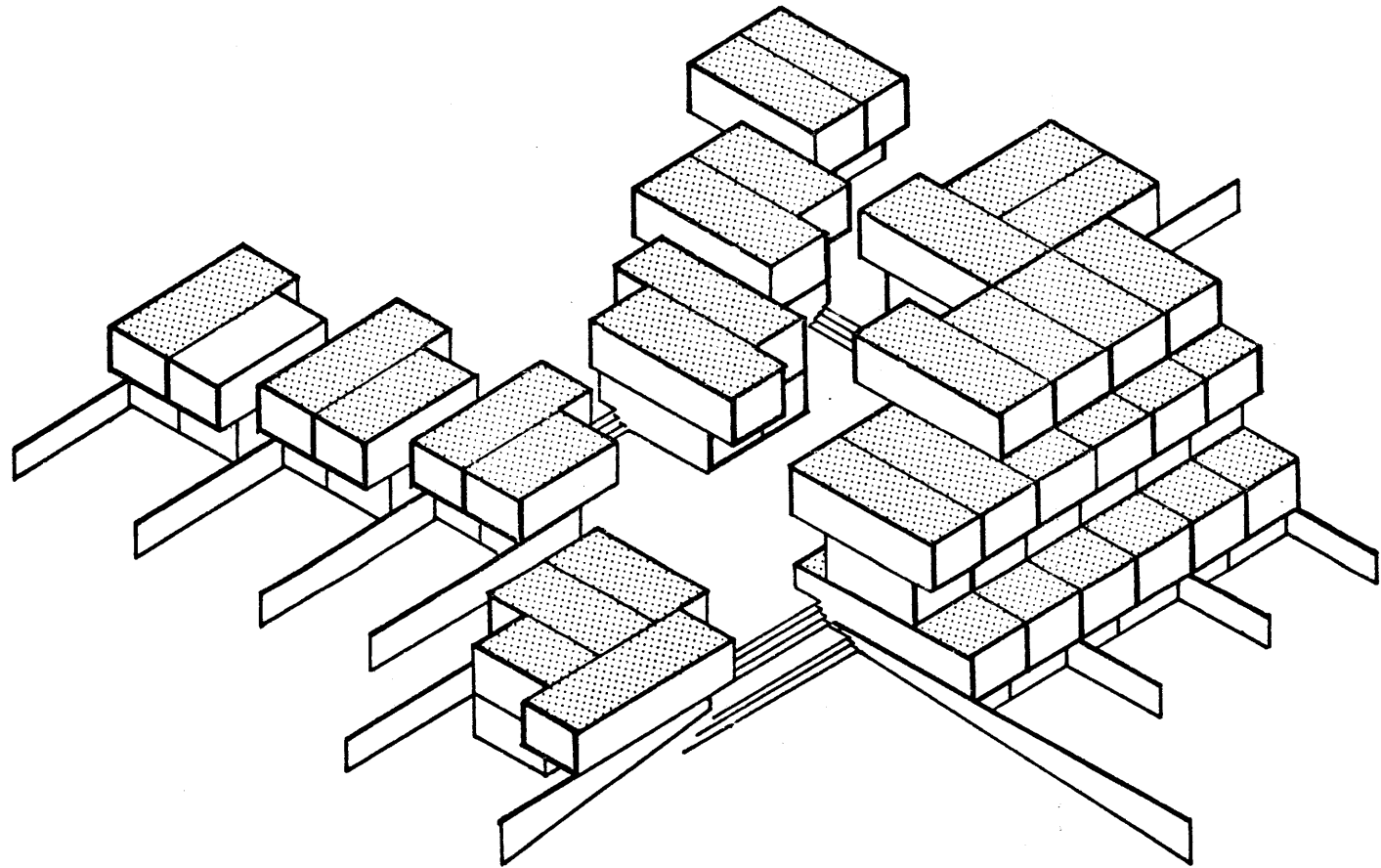


Regular



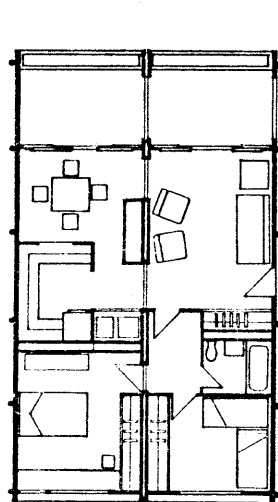
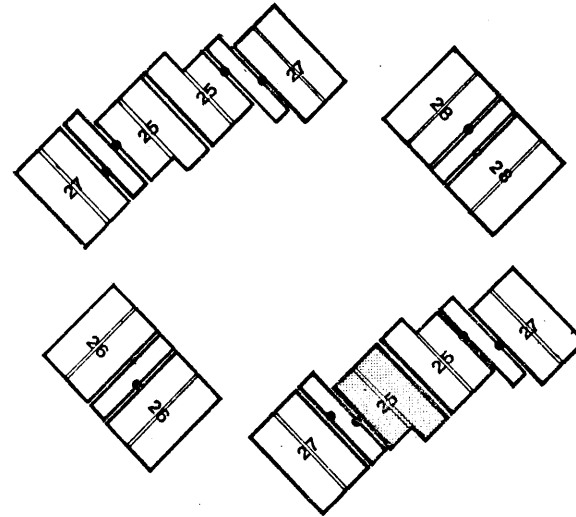
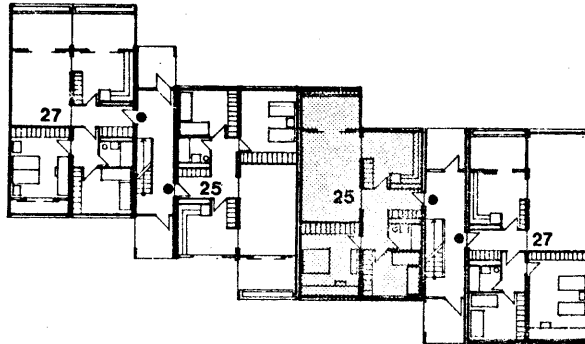
Irregular



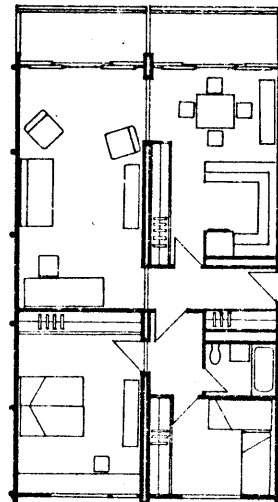


HILLSIDE HOUSING

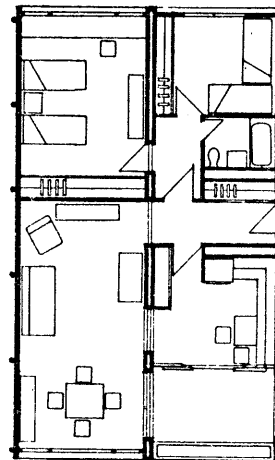
2-BEDROOM APARTMENTS



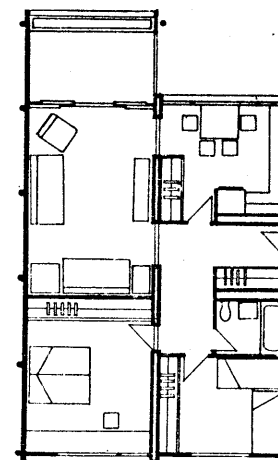
● 26



● 28

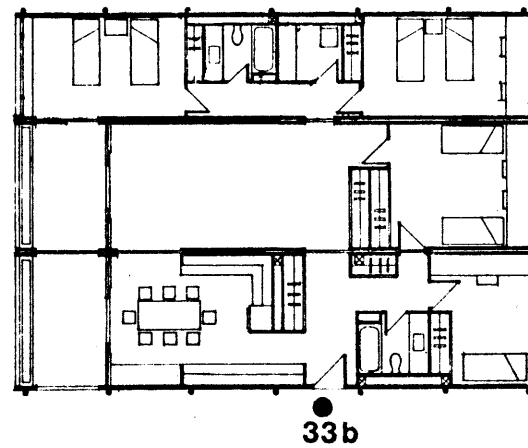
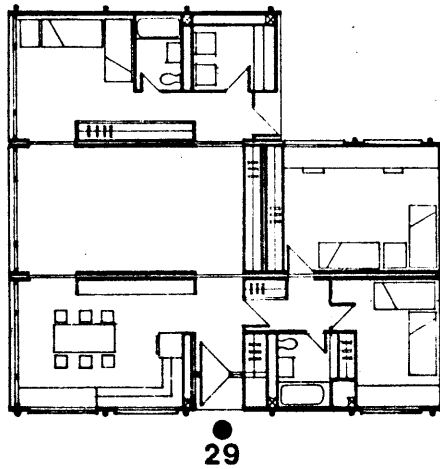
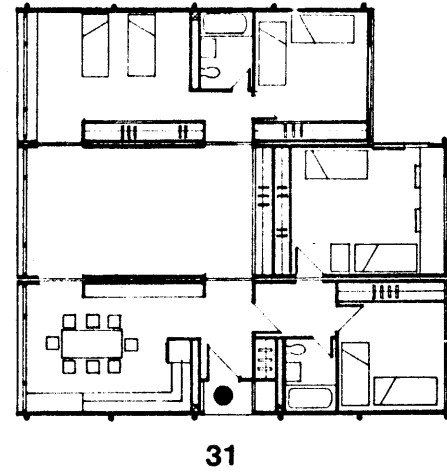
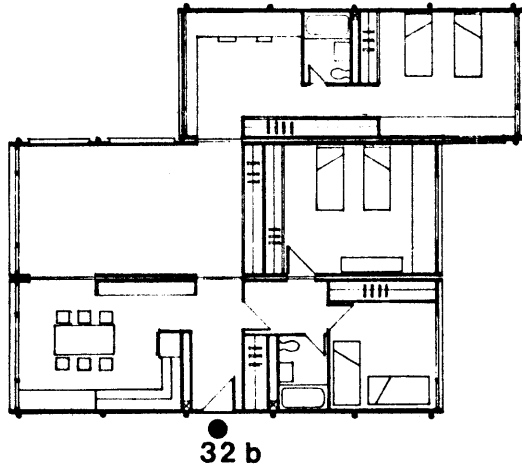


● 27

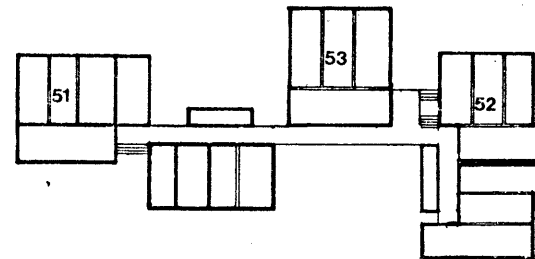
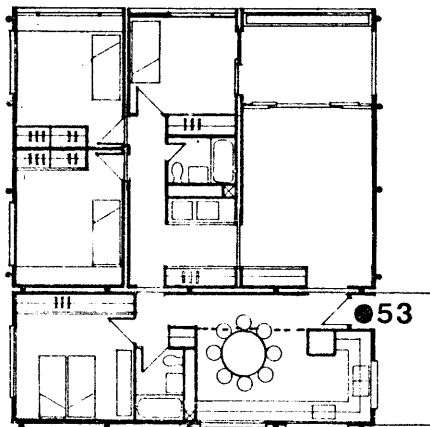
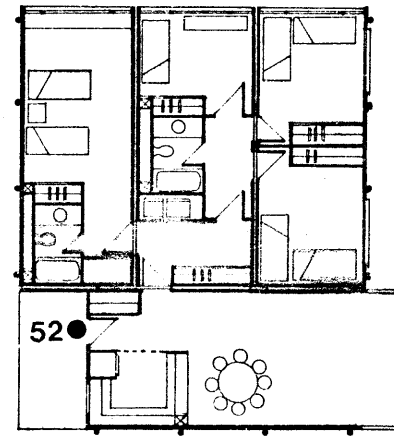
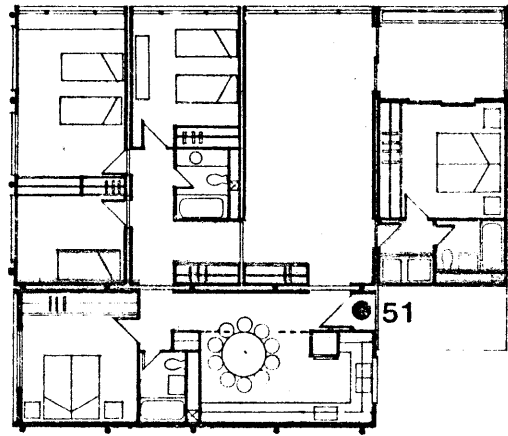


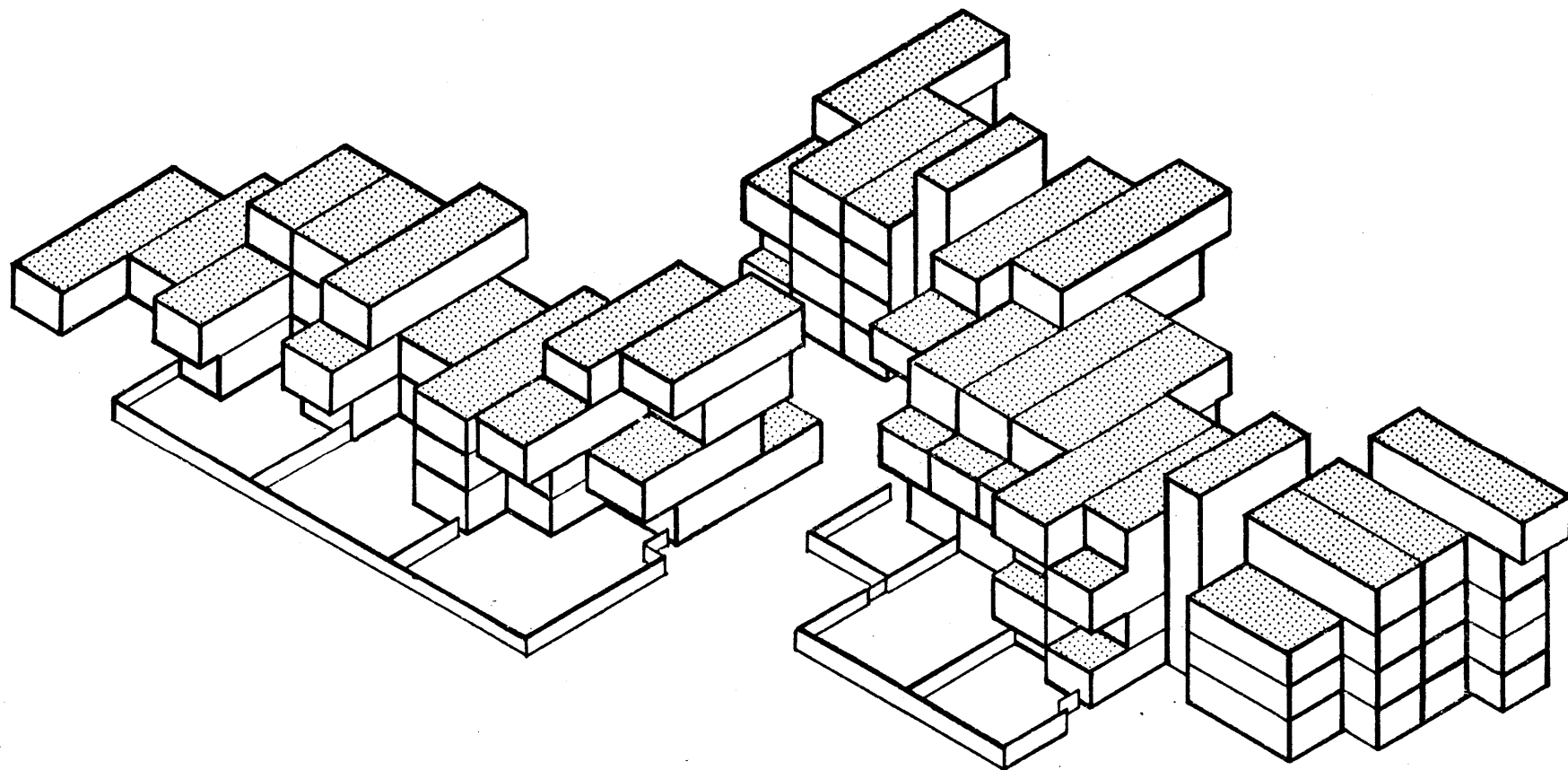
● 25

3 & 4 BEDROOM APARTMENTS



4 & 5 BEDROOM APARTMENTS





CLUSTER HOUSING

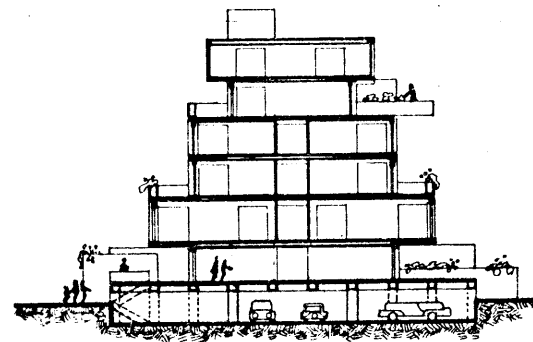
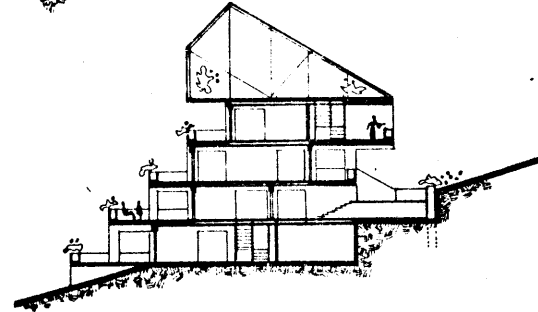
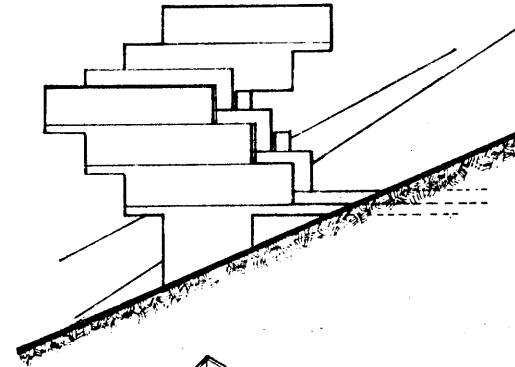
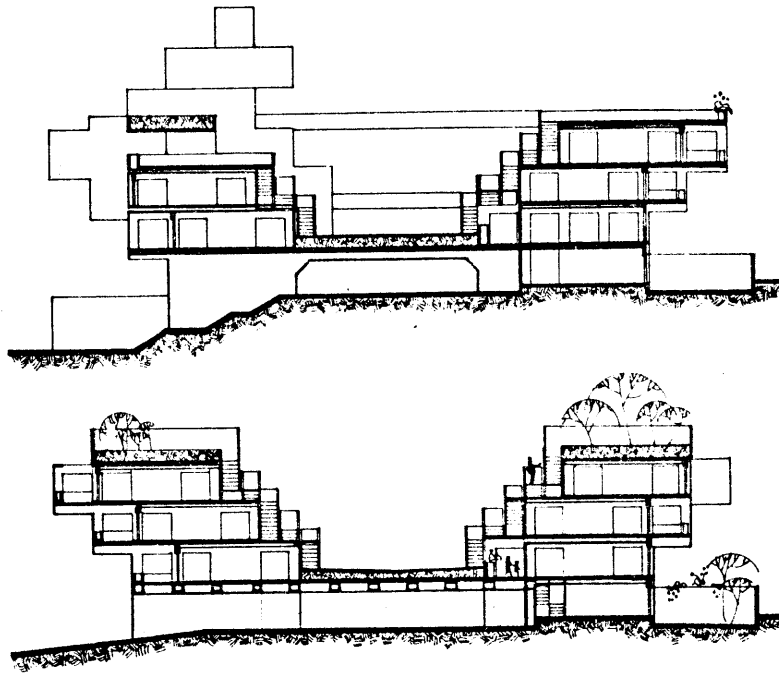
TERRACED, INVERTED, AND STAGGERED HOUSING

Some of the more unconventional designs proposed for use with the OFFSET SYSTEM are shown schematically on the opposite page.

These buildings can be terraced, inverted, and staggered, as well as using cantilevering sections.

The examples of buildings terraced into the hillside or as pyramid-types are more promising for development than the inverted types which would require special structural considerations.

From an architectural point of view, the proposed system is very flexible. It adapts well to a wide variety of conventional building types shown earlier, as well as town houses, walk-ups, cluster groupings, and the "offset" types shown here.



ABSTRACTIONS: "OFFSET" HOUSING

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It is difficult to adequately thank the persons who have contributed so much to make this thesis possible. The brief acknowledgements which follow can only serve to indicate a portion of the effort and influence given.

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Building Systems and Industrialization
Massachusetts Institute of Technology

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Co-advisor
Department of Architecture
Massachusetts Institute of Technology

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Department of Architecture
Massachusetts Institute of Technology

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Reinhard Goethert
Urban Settlement Design in
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Massachusetts Institute of Technology

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Ms. Deborah Forschman, Engineer, for preliminary calculations on box-unit slab dimensions,
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For part of the typing: Mrs. Carol McSweeney
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ACTIVE HOMES, Marlette, Mich.
AMERICAN HOME IND., Calif.
BATIMETAL
*BOISE CASCADE, Boise, Idaho
BRIGGS
CARDINAL INDUSTRIES, Columbus, Ohio
CASTLE HOMES, North Carolina
CHANNEL BUILDING CO,
DAVIDSON IND., Southport, Ind.
DELMARA HSG. CORP. Princess Anne, Maryland
DESCON INTERNATIONAL, Montreal, Canada
DESIGN HOMES, INC. Prairie du Chien, Wisc.
DONN BLDG. SYSTEMS, Medina, Ohio
DYNAMIC HOMES, Minnesota
ECHO GROUP, INC. Fort Lauderdale, Fla.
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NATIONAL HOMES
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SAVINA, Wichita, Kansas
SCOTTY'S, Pembroke Pl., Fla.
UNION MFG. & SUPPLY, Colorado
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USDC, Arlington, Va.

* Mr. John T. Daly, A.I.A., was particularly helpful with his 2-page reply in detail. Architectural Services Manager for Boise Cascade.

Crane manufacturers whose information is incorporated in Chapter V are:

AMERICAN HOIST & DERRICK CO.
63 S. Robert St., St. Paul, Minnesota 55107

AMERICAN POCLAIN CORP.
300 S. Randolphville Rd., Piscataway, N.J. 08854

CLARK EQUIPMENT CO.
Lima Division, Lima, Ohio 45802

GENERAL CRANE INDUSTRIES, LTD.
670 Industrial Road, London, Ontario

GROVE MANUFACTURING CO. (Division of W. Kidde & Co.)
Shady Grove, Penn. 17256

HARNISCHFEGGER P & H (No response)

KOEHRING (Lorain Division)
Chattanooga, Tenn. 37405

LIEBHERR CRANE CORP.
4100 Chestnut Ave. Newport News, Va. 23605

LINK-BELT SPEEDER (Div. of FMC Corp.)
Cedar Rapids, Iowa

MANITOWOC ENGINEERING CO.
Dept. 7316 Manitowoc, Wisc. 54220

NORTHWEST ENGINEERING CO.
201 W. Walnut St.
Green Bay, Wisconsin, 54305

Numerous manufacturers are referred to in the thesis and are again thanked for their prompt replies to requests for information.

